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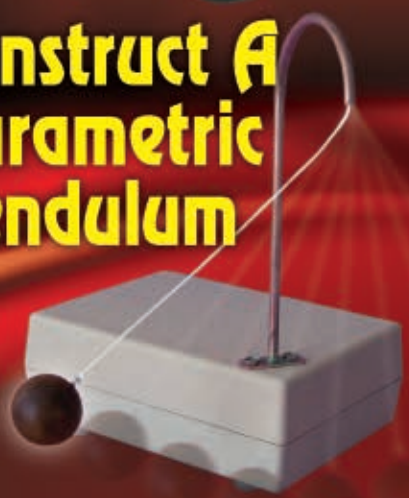

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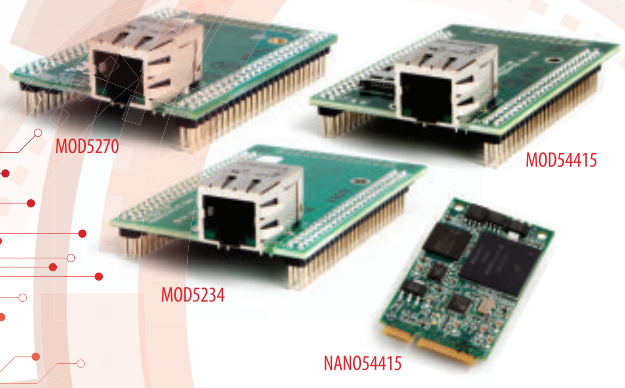

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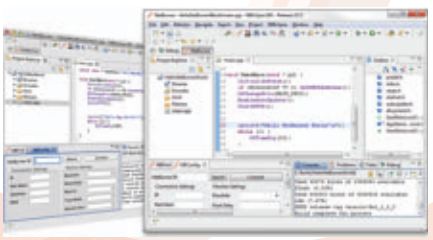

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June 2014

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■ *By Robert Reed*

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This easy-to-build-and-use tester will help you quickly troubleshoot problems like bad I/O pins, issues with RAM, and other headaches you might be having with the Stamps you're using in projects.

■ *By Chris Savage*

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50 MakerPlot — The DIY Software Kit ... Part 9

Learn all about Event Codes, which are the instructions that make every switch, button, and textbox control an Interface so it does what you want it to do.

■ *By John Gavlik and Martin Hebel*

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Sharpening Your Tools of Creativity

Construct a Battery-Backed UPS for Your Pi

Protect your Pi during power outages for a fraction of the cost of commercial uninterruptable power supply units.

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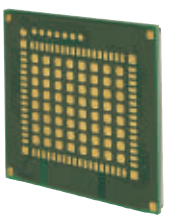
The Latest in Networking and Wireless Technologies

The Internet of Things and Machine-to-Machine Communications Emerge as Internet Drivers.

Both of these communications technologies that are used to monitor and/or control equipment by way of the Internet are expected to enable billions of new devices in the coming years.



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This time, learn about inputting analog signals using the analog-to-digital converter built into the Arduino, plus some basic electrical concepts to help understand what it is that's being input.

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Advanced Techniques for Design Engineers

The Dawn of a New EVE.

This is the first in a series of tutorials aimed at enabling FTDI's new Embedded Video Engine technology using a PIC microcontroller. Along the way, we will use Microchip's XC32 C compiler to code the various elements of our EVE firmware driver. Plus, with the help of a PICkit3, we will exercise this driver onboard a Digilent MX3 which is based on the PIC32MX320F128H.

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Nuts & Volts (ISSN 1528-9885/CDN Pub Agree #40702530) is published monthly for $26.95 per year by T & L Publications, Inc., 430 Princeland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@nutsvolts.com.

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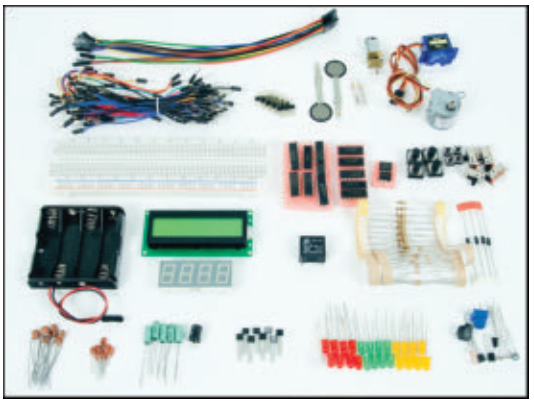

The chipKIT Starter Kit provides a wide range of sensors, actuators, and electronic components at a remarkably low cost, enabling the construction of an endless array of projects that can serve to inform beginners or empower experts. The kit has been designed for use with our chipKIT™ boards, 32-bit microcontroller-based platforms that are compatible with much of the existing Arduino® code base, reference material, and other resources.

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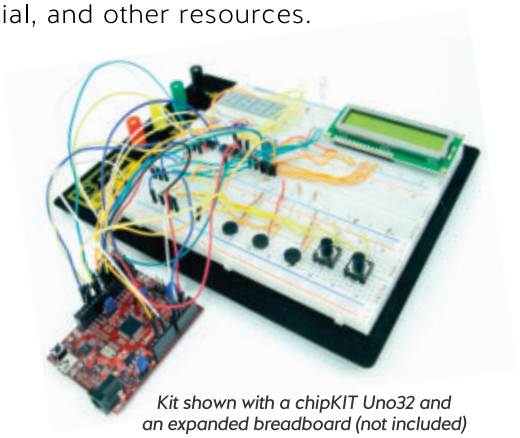

Kit shown with a chipKIT Uno32 and an expanded breadboard (not included)

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DEVELOPING PERSPECTIVES

Can't Get There From Here

My most frequent email inquiry is some version of "I've been doing transistors and resistors for 30 years, how do I get into microcontrollers?" The readers that send in these inquiries invariably conclude that they simply can't get there from where they stand. That may be true, but it comes down to a matter of perspective.

What I mean is that learning is really about forming links to existing memories (the psychologists call it association), as well as forming new relatively stand-alone ones (accommodation).

Assimilation is easy because the new knowledge — say, how a microcontroller operates — fits nicely into what we already know about electronics. However, in reality, microcontrollers don't really map well to, say, capacitors.

Accommodation takes a lot more effort. You have to build a new model of the universe. You might even have to change your mind about some long-held beliefs. For someone moving from a few decades of work with analog components, a modern microcontroller is really a new universe.

Sure, there are pull-up resistors on I/O ports and capacitors to filter the power supply spikes. However, for the most part, there is little crossover from analog component to digital microcontroller.

I think the frustration comes in when someone who has been in electronics for decades picks up, say, a PIC or Arduino and expects to know how to use it in five minutes. It's the expectation that's the problem. In reality, old knowledge just doesn't transfer.

Whether using and/or learning theory, becoming fluent in microcontrollers involves a lot of accommodation.

Children and younger adults often have an easier time picking up microcontrollers, relative to someone with years of experience with analog circuits. This is — in part — because they have no legacy knowledge to get in the way. They don't have any preconceived (and wrong) notions on how the device should work, based on their experience with discrete analog components.

So, if you're one of those frustrated readers, the solution is to adjust your expectations. Admit to yourself that you're a novice when it comes to microcontrollers. Open your mind to new ideas and stop trying to fit the digital world into your analog universe.

In addition to the "think different" approach, you need to have some hands-on experiences to cement what you learn. I usually suggest picking up a $20 Arduino Uno and spending a few weeks going through the example code that's part of the integrated development environment (IDE) that's available online.

Turns out you can get there from here, as long as you're willing to nudge "here" a bit. **NV**

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Published Monthly By
T & L Publications, Inc.
430 Princeland Ct.
Corona, CA 92879-1300
(951) 371-8497
FAX **(951) 371-3052**
Webstore orders only **1-800-783-4624**
www.nutsvolts.com

Subscriptions
Toll Free **1-877-525-2539**
Outside US **1-818-487-4545**
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READER FEEDBACK

Flying High

I am so happy that Walt Noon put his article about his home-built flight sim in the April 2014 issue! I just had to share that with you. I am now collecting the materials for the sim. Thanks to you for your mag and to Walt for taking the time to share with us.

David Twyford

A Cautionary Tale

After reading Bryan Bergeron's perspective in the May 2014 issue, I have been inspired to think of hazards relating to 3D printing that would have otherwise never occurred to me.

The hazard is the microscopic slivers Bergeron found in his fingers. They could be problematic in many ways like glass fibers. What if the plastic slivers work their way into the blood stream? What if the dust gets into the eyes (contacts)? What happens if the dust is inhaled? What are the long-term health issues from the above questions? Remember how long asbestos was in use before we learned of its hazards?

It seems to me that it will be best to err on the side of caution, and take all possible precautions to protect oneself from the potential hazards — real or imagined.

Gene Melton
St. Augustine, FL

Good points, Gene, especially given the history of asbestos. Remember, it used to be used in

Continued on page 24

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■ BY RON HACKETT
www.jrhackett.net

Construct a Battery-Backed UPS for Your Pi

This month's installment was prompted by a recurring problem I have. I happen to live in an area that, for some reason, is plagued by very brief but frequent power outages. Almost every day, the power provided by the local electrical utility drops out for a fraction of a second at least once, and sometimes more often. As a result, my computers, monitors, and printers are protected by several commercial uninterruptable power supplies.

Naturally, each of my Raspberry Pi computers is also protected in the same manner. However, that doesn't really solve my problem because my ultimate goal for at least one of them is to install it in my backyard shed (which also serves as an outdoor kitchen and smokehouse), so that I can monitor and control the temperature of my smoker from my cell phone. I don't want to buy yet another commercial UPS because replacing all those 12V gel cells every few years has become an expensive proposition.

The UPS that we're going to construct this month should be able to protect my Pi as well as a commercial UPS at a fraction of the cost. Of course, only time will tell for sure, but my "smoker" Pi will also monitor its backup batteries and hopefully warn me of any impending problem. I do realize that not many Primer readers will also have a backyard smoker that needs controlling, but I'm sure you can find your own idiosyncratic uses for a simple battery-backed UPS for one of your PICAXE-Pi projects, so let's get started!

Designing the UPS Circuit

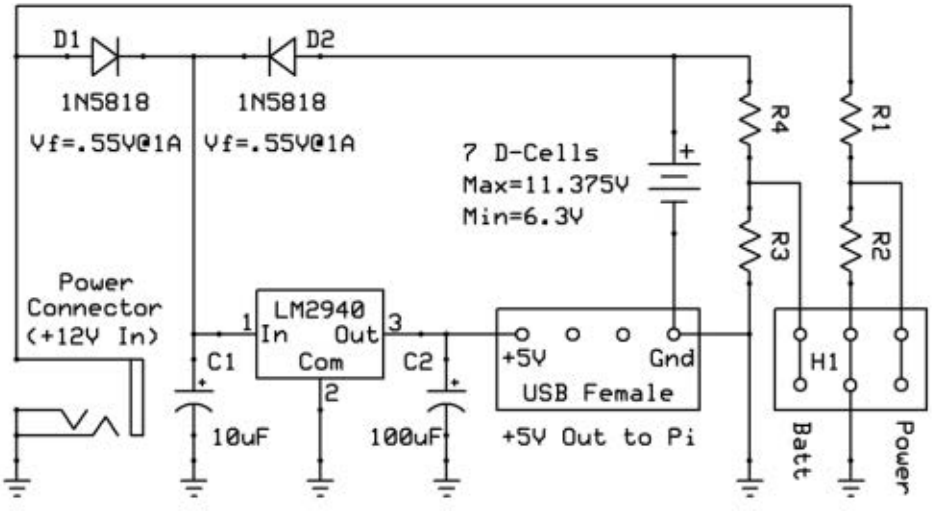
When I first began thinking about a UPS for the Pi, I had two major requirements in mind:

- It should provide 1A at 5V — the same as a typical USB power supply.
- It should be inexpensive and simple to construct.

With those two requirements in mind, I chose to use ordinary non-rechargeable alkaline batteries rather than a rechargeable gel cell. The resulting schematic is presented in **Figure 1**, and several of its features require a brief explanation.

Main Power Source

I used a switching 12V wall wart power supply because I happened to



■ FIGURE 1. UPS schematic.

have one available. A linear 12V supply would probably also work, but I don't have one that can supply 1A to test that assertion. The main requirement is that the supply is powerful enough so that its output voltage doesn't decrease much below 12V when it's supplying power to the Pi. If it did, the batteries would kick in and be unnecessarily depleted.

Alkaline Batteries

I chose to use alkaline batteries because they are reasonably inexpensive with a relatively high energy density. However, two questions remain: Why D cells, and why seven of them? D cells may be larger than necessary, but many retailers sell them at about the same price as C cells, so why not?

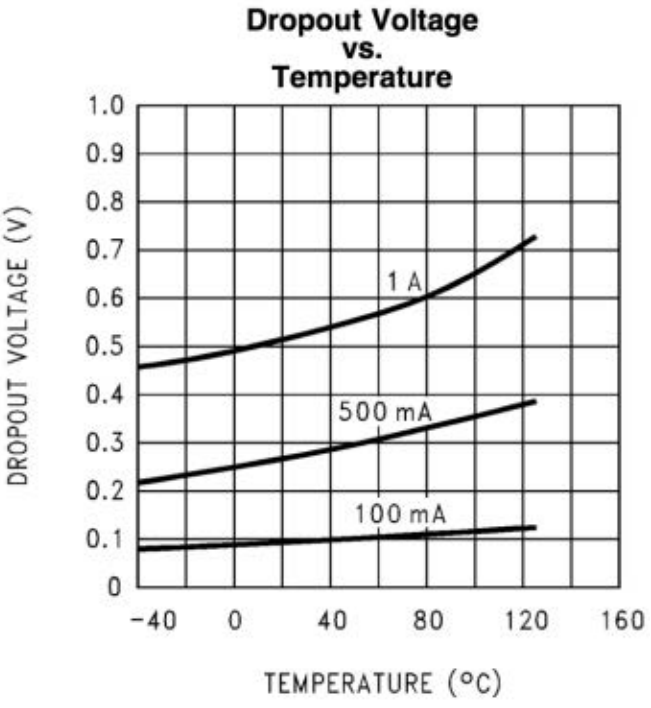
Why seven of them? As you know, all alkaline batteries are rated at 1.5V. However, their initial voltage is actually somewhat higher. I measured the voltage of each battery in a fresh set of alkaline D cells, and found that they averaged 1.625V each. Seven times 1.625V = 11.375V; with that in mind, refer to the schematic in **Figure 1**.

You can see that diodes D1 and D2 effectively isolate the two sources of power (12V main power and battery power). In normal operation, the 12V from the main power supply is greater than the 11.375V provided by a fresh set of seven D cells.

As a result, the battery voltage is effectively blocked by the higher 12V supply. Therefore, the main 12V supply reaches the voltage regulator, and the batteries are not drained at all.

If the battery pack contained eight cells, it would initially output 13V (8 * 1.625V = 13.0V) which would block the main supply and quickly drain the batteries down below 12V. At that point, the main supply would again block the battery supply and power the circuit. The net result is that eight D cells would cause the battery pack to be unnecessarily depleted; using seven D cells avoids this problem.

Before we move on to the next feature in the schematic, there's one more point about alkaline batteries that needs to be made clear. Diode D2 is especially important in the circuit because attempting to recharge an alkaline battery can cause the battery to explode! If you don't believe me, read the warning label on every alkaline battery.



■ FIGURE 2. LM2940 dropout voltage.

LM2940 Voltage Regulator

All linear voltage regulators have a characteristic known as the "dropout" voltage (V_{DO}). This term refers to the minimum difference between V_{in} and V_{out} that's required for reliable regulation. For example, the LM7805 (which we've used in many of our projects) has a V_{DO} of 2.0V, which means that V_{in} must be greater than 7V in order to maintain a regulated 5V output.

The LM2940 is what's called a low dropout (LDO) regulator because its V_{DO} is relatively small; it's usually listed as 0.55V. However, using a fixed value for V_{DO} can be somewhat misleading because a regulator's V_{DO} can vary significantly with temperature and with the amount of current flow. In order to see how large the variance can be, refer to **Figure 2** which presents the V_{DO} graph that's included in the LM2940 datasheet.

First of all, it's obvious that current flow makes a considerable difference in the LM2940's V_{DO}; at 1A, it's roughly six times higher than it is at 0.1A. Also, V_{DO} varies directly with temperature, but not as much as it does with current flow. Unfortunately for us (but not the rest of the civilized world), the temperature in **Figure 2** is in Celsius. In order to make the graph easier to read, consider the following two equivalencies: -20°C = -4°F, and 40°C = 10°4F. Since I wouldn't venture out to the backyard beyond either of those two extreme temperatures, let's focus on the more temperate portion of the graph.

At 1A of current, V_{DO} varies approximately between 0.45V and 0.55V, so we can use 0.6V as a generous estimate of the maximum V_{DO} for the LM2940. One final point about the V_{DO} graph presented in **Figure 2**: The lines terminate at 125°C because that's the maximum operating temperature of the LM2940.

If you look back at the schematic presented in **Figure 1**, you'll see that I listed 6.3V as the minimum voltage for the battery pack. A single-cell alkaline battery is fully depleted ("dead") at 0.9V, so our seven-cell battery pack will be depleted at 6.3V (7 * 0.9V). However, whenever the battery pack is powering our PICAXE-

Pi circuitry, its voltage also passes through diode D2 which has a forward voltage drop (V_f) of 0.55V at 1A. Therefore, in the worst-case scenario (i.e., a dead battery pack), V_{in} for the LM2940 will be 5.75V (6.30V – 0.55V) or less, so the circuit should function correctly until the battery pack is fully depleted at 6.3V.

Of course, we're going to use a PICAXE processor to monitor the functioning of our UPS. We'll display the real time data for two variables: the voltage of our main power supply; and the voltage of our backup battery pack. So, let's again turn our attention to the two voltage-sensing circuits in the schematic of **Figure 1**.

Voltage-Sensing Circuit (R1 and R2) for the Main Supply

We don't need to know the actual voltage of the main power supply. We're only interested in whether it's good or if it has failed. Therefore, we don't need an ADC (analog-to-digital converter) input for this purpose; we just need to choose R1 and R2 to produce a digital high or low voltage at an input pin on the PICAXE. In order to do that, we need to know the minimum voltage level that results in a high input when using a 3.3V supply.

There are some differences between PICAXE processors, and even between specific pins on any given processor. The details are presented in the documentation for the *inputtype* command in Section 2 of the PICAXE manual. However, rather than bore you with those details, we'll simply use a value of 2.7V which exceeds the minimum voltage level necessary to produce a high level on all input pins of all current PICAXE processors.

With a 12V supply and a 0.55V voltage drop across the 1N5818 diode, if we choose a 68K resistor for R1 and a 22K resistor for R2, the standard voltage divider rule yields the following result:

$$V_{out} = \frac{R_2}{R_1 + R_2} \bullet V_{in} = \frac{22k}{68k + 22k} \bullet$$

$$(12V - 0.55V) = \frac{22}{90} \bullet 11.45V = 2.80V$$

Therefore, if the line that's labeled "Power" in the schematic is connected to a PICAXE input pin and the 12V main power supply is functioning correctly, the input pin will be in a high state. On the other hand, if the main power supply goes down, R2 will pull the Power input down to ground, so the input pin will be in a low state. This gives us a simple way to know whenever the main power goes down. We could also set up a PICAXE interrupt routine, so that the program could immediately respond to the main power outage.

There is an important caution about the main supply that I need to mention. Typical wall wart power supplies frequently output a voltage that's less than or greater than the stated value. If the voltage is much below 12V, the input pin may not be in a high state. More importantly, if the power supply's actual voltage is 14V or higher, the input pin will be at a level that's higher than 3.3V which could damage the pin. Therefore, it's important to test the specific 12V supply you intend to use *before* connecting the Power line to an input pin on the PICAXE processor. This needs to be done when the Pi is being powered by the main supply because the voltage level can change significantly, depending on whether or not it's actually providing power.

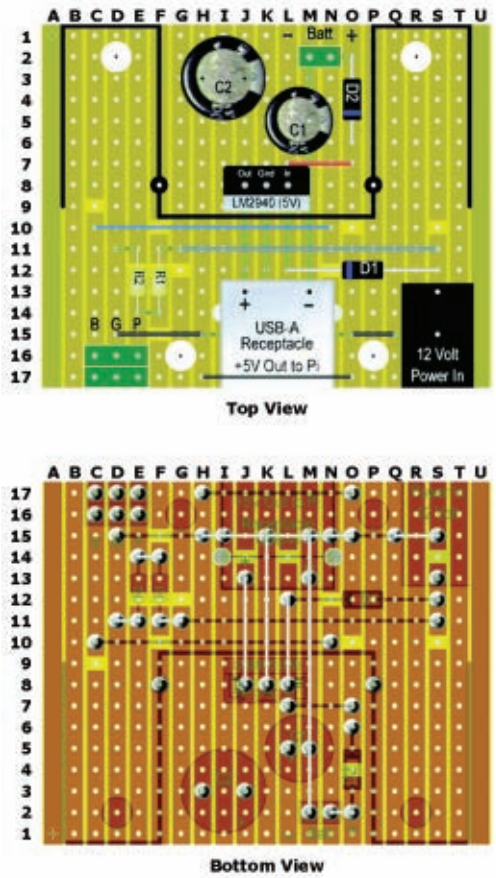
To check the voltage of your main supply, power the Pi from it and measure the voltage at the power connector on the UPS. The pin at the back end of the connector is +V and the shell of the USB connector is grounded, so it's easy to do with the probes of a multimeter.

Voltage-Sensing Circuit (R3 and R4) for the Battery Pack

For the backup battery supply, we're definitely interested in monitoring the real time analog voltage level, so we need to connect the UPS "Batt" line to an ADC input on the PICAXE processor. We also need to choose appropriate values for R3 and R4. When I first built my UPS, I included all four resistors on the stripboard circuit. However, as I was testing the supply, I realized that I needed to experiment further with different values for R3 and R4.

To do so, I removed R3 and R4 from the UPS, and modified the stripboard circuit so that the Batt line was directly connected to the positive terminal on the battery pack. (After we've constructed the UPS, we'll discuss this issue further.)

Finally, in the schematic of **Figure 1**, the Power line, the Batt line, and ground are attached to H1 (a 2x3



■ FIGURE 3. Stripboard layout (two resistors).

male header), so that a ribbon cable can be used to connect those three lines to a breadboard circuit.

USB Connector

The USB connector in the UPS schematic is a standard USB Type A receptacle. Its two data pins (pins 2 and 3) are not used in the circuit; I just snipped them off before soldering the connector in place. In order to power the Pi from the UPS, you will need a standard USB cable with a Type A male connector on one end and a Micro B plug on the other end to connect to the Pi.

Heatsink

Although it isn't shown in the schematic, the LM2940 requires a heatsink in order to be able to provide sufficient power to the Pi. We'll discuss heatsinks in more detail in the next section.

Constructing the Stripboard Circuit

As I mentioned earlier, I originally built two different versions of the UPS stripboard circuit — one that included all four sensing resistors, and a second one that only included R1 and R2 so that I could experiment with changing the values of R3 and R4 on my breadboard circuit. In the remainder of this article, we're going to discuss the results of those experiments, so **Figure 3** presents the second layout (only R1 and R2 are included). However, I realize that not everyone will want to run the same experiments, so full page versions of both layouts are available for downloading at the article link.

In the layout of **Figure 3**, the black line (running up and down from the left side to the right side of the stripboard) represents the shape of the heatsink that I used for this project. It may seem unusually large, so I probably should explain why I chose that specific heatsink.

Before I constructed either of the two layouts I have already mentioned, I built a simpler stripboard circuit that only included the 12V supply, the voltage regulator, and the necessary support circuitry. I did that because I wanted to make sure the LM2940 could supply sufficient current to power the Pi without over-heating. In that circuit, I just used one of several smaller heatsinks that I had on hand.

As it turned out, the LM2940 was able to do the job, but it ran so hot that I wasn't able to touch it for more than a fraction of a second. I was concerned that the excessive heat could eventually destroy the power supply, so I began a search for a more massive heatsink. My main requirement was that all the components should fit within the width of a standard stripboard, and the heatsink I finally chose (Digi-Key #HS410-ND) works well for that purpose.

I also decided to use a thermal pad (Digi-Key #BER168-ND) because it can significantly improve a heatsink's ability to dissipate heat. I have been continuously powering my Pi from the UPS for more than two weeks now, and the heatsink is only warm to the touch.

ITEM	DESCRIPTION
Batteries, 7 Alkaline D-Cells	None
Battery Holders (2 pieces)**	None
Capacitor, 10 µF, Electrolytic	C1
Capacitor, 100 µF, Electrolytic	C2
Connector, Power	12 Volt Power In
Connector, USB	USB-A Receptacle
Diode, 1N5818	D1 & D2
Header, Male, 2 pins	Battery
Heatsink, Digi-Key #HS410-ND	None
Resistor, 68K, 1/4 Watt	R1
Resistor, 22K, 1/4 Watt	R2
Resistor, **??K**, 1/4 Watt	R3 (**Varies** — see text)
Resistor, **??K**, 1/4 Watt	R4 (**Varies** — see text)
Thermal Pad, Digi-Key #BER168-ND	Optional
Stripboard, 19 traces with 17 holes	None
Voltage Regulator	LM2940 (5V)

**RadioShack #270-396 or similar

■ FIGURE 4. Parts List.

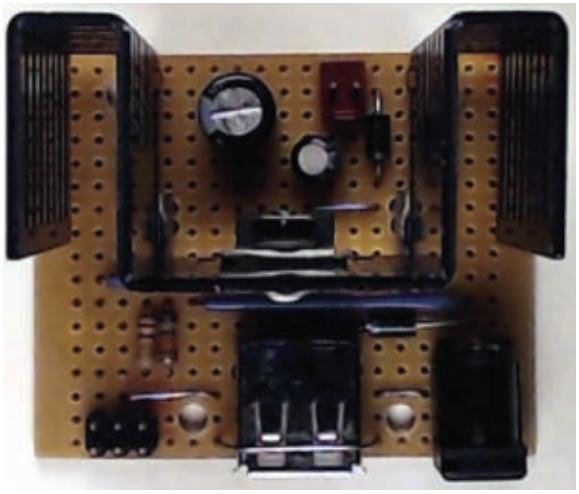
Figure 4 is the Parts List for the UPS project. Except for the batteries, battery holders, heatsink, and thermal pad, all the required parts are available on my website (**www.JRHackett.net**). In order to conserve space in this article, the detailed assembly instructions for both versions of the UPS are available at the article link. However, there's one aspect of the construction process that I do want to mention.

The current-carrying capacity of a PCB (printed circuit board) trace depends on the width and thickness of the trace. On a stripboard, the traces are about 0.08" wide, but they also contain numerous holes which are about 0.04" wide, leaving about 0.04" as the effective width of each trace. I did a fair amount of online searching, but I haven't been able to determine the thickness of the stripboard trace. (It probably varies from one manufacturer to another.)

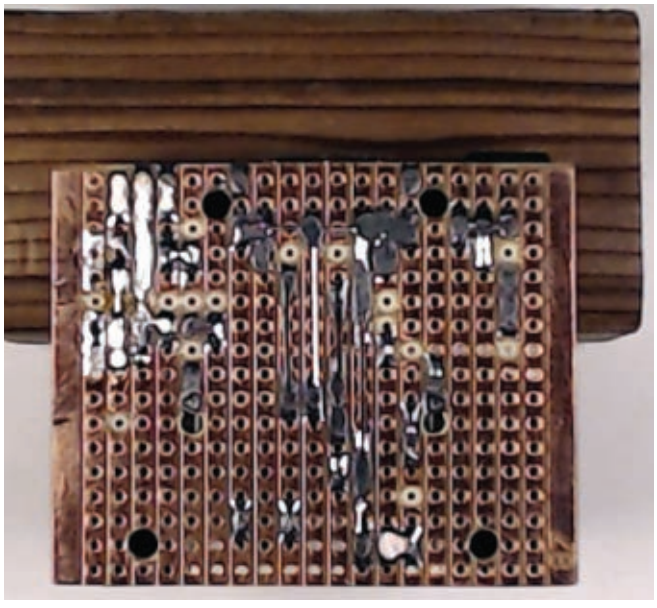
I also did some searching to gather opinions as to whether it's safe to use a stripboard to source a full amp of current, but all I found was a considerable amount of disagreement!

Rather than risk the possibility of constructing an unreliable (or even self-destructing) power supply, I decided to "beef up" the power and ground traces that supply power from the main 12V source and from the battery pack. If you refer back to the bottom view of the stripboard layout in **Figure 3** and focus on the traces in columns J through M, you can see that I added bare jumper wires to those traces wherever the power and ground lines could be carrying a full amp of power.

Of course, you may decide this precaution is not necessary. However, if you do decide to take the same approach, the provided assembly instructions include the



■ FIGURE 5. Top view of completed UPS board.



■ FIGURE 6. Testing the UPS board.

■ FIGURE 7. Completed UPS on mounting board.

details of how to install the necessary jumpers. **Figure 5** is a photo of my completed UPS board; you may want to refer to it as you construct this project. (Before we continue, I need to mention something about the photos in this article. My digital camera recently "died," and I have been too busy to replace it yet, so I used a webcam for all the photos. As a result, they aren't as clear as I would like — sorry about that!)

Testing the Stripboard Circuit

After you've built the UPS, it would be a good idea to check and double-check your completed stripboard circuit for accidental shorts and other wiring problems before applying power. When you're ready to test and apply power, you will need a way to support it in an inverted position so that you can use a multimeter to check for the correct voltage (+5V) at the USB connector. I used a small piece of 1.5" square scrap wood for this purpose (see **Figure 6**), but you can use any arrangement that holds the completed stripboard in a stable inverted position.

To do the testing, connect the main power supply and the battery pack to the board, and carefully invert it so that it sits reliably, and is in the same orientation that's shown in the layout of **Figure 3**. Locate points J13 (+5V) and M13 (ground), and carefully (because the board is powered) determine that a voltage very close to +5V is being supplied to those two points. If it is, remove the main supply connection and test those two points again.

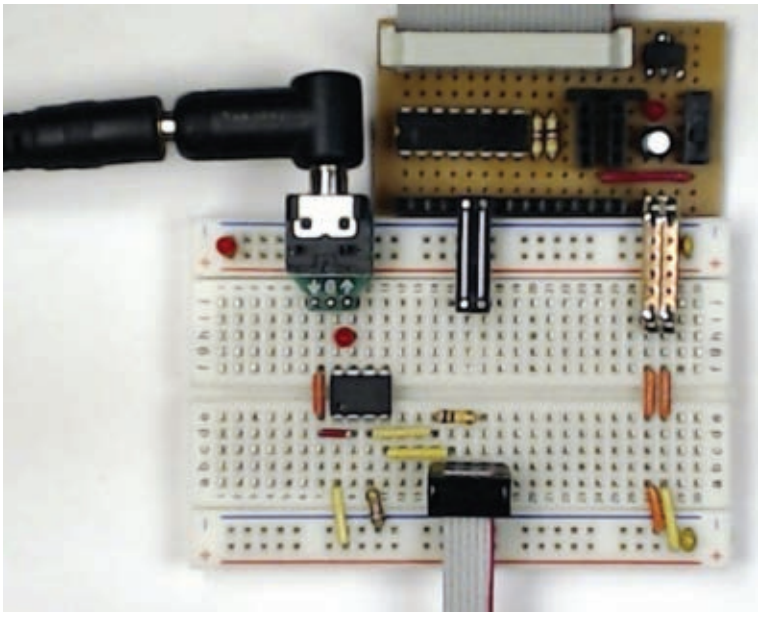
The same voltage should be seen because the battery pack is now supplying the circuit. If your board does not pass these two tests, you need to do some troubleshooting.

When you're sure the board is functioning correctly, we're ready to move on to final testing of the UPS when it's actually powering the Pi. However, before doing that, you may want to secure the battery holders, batteries, and the UPS stripboard on some sort of mounting board, as well. I used a piece of 1/2" plywood for this purpose (see **Figure 7**).

In the photo, the odd-looking eighth "battery" is actually a wooden dowel with a bolt running through its center. You can just solder a wire in its place, if you prefer.

When you're ready, connect the main power supply and the battery pack to the UPS, and use a suitable USB cable to connect the UPS to your Pi — which should immediately begin its boot-up process. When your Pi has completed booting, measure the voltage between the two ends of the battery pack and make a note of it. Next, unplug the main power supply. The Pi should continue to run without interruption. Again, measure the voltage between the two ends of the battery pack; it should be significantly lower when it's providing power.

My battery voltage dropped from 11.3V to 10.5V, but I had already been doing a considerable amount of UPS testing so your voltage levels will probably be somewhat higher. This is an important point to keep in mind because we will be measuring the battery voltage when it is not powering the Pi. Consequently, we need to be sure to replace the batteries well before they reach the "spent" level of 6.3V. (I plan to replace my batteries when they drop below 7.5V.)



■ FIGURE 8. Breadboard circuit for UPS experiments.

Experimenting With the UPS Voltage-Sensing Circuitry

Now that our UPS is functioning correctly, we're ready to conduct a couple of simple voltage-sensing experiments. Even though we won't be communicating with the Pi this month (that's still on my "To Do" list), I used our Pi interface board (from the August 2013 Primer) for these experiments because we need to power everything at 3.3V. Our Pi interface board is a convenient way of doing that. If you have a 3.3V breadboard power supply, that would work just as well.

Figure 8 is a photo of my breadboard circuit for the following two experiments. I haven't included a schematic because the necessary connections are very simple. The six-wire ribbon cable is inserted into the breadboard with a double-ended three-pin male header. (You can also use a 2x3 pin header, but it isn't necessary because each pair of pins — 1 and 2; 3 and 4; and 5 and 6 — carries the same signal.)

The other end of the ribbon cable is inserted into the 2x3 male header on the UPS, with pin 1 (the red stripe on the cable) inserted into the "B" (battery voltage) line. Therefore, on the breadboard, the three connections (in order from left to right) are main power voltage (divided down), ground, and battery voltage (not divided). The ground connection is made underneath the cable, so it isn't visible in the photo.

At this point, I need to mention an important caution before we proceed. The battery voltage at pin 1 (red stripe) of the ribbon cable is not divided, so it can be as high as 11.375V. Therefore, **directly connecting pin 1 of the ribbon cable to a PICAXE (or Pi) I/O pin is likely to damage or destroy the I/O pin!**

Experiment 1: Battery Pack Voltage Sensing

We're going to use a simple two-resistor voltage divider circuit, execute a *readadc10* statement to measure the voltage at the junction of the two resistors, and then compute the battery voltage. The Microchip documentation for PIC micro devices (on which all PICAXE processors are based) indicates that a total resistance of about 10K will produce the most accurate ADC reading. However, the two resistors will always be in the circuit, so they will produce a continuous current-drain on the batteries.

At the maximum battery voltage of 11.375V, the current drain of a 10K (total) voltage divider would be more than 1 mA. That might not seem very large, but I was concerned that over time it would significantly reduce the life span of the batteries.

In order to determine how much accuracy would be lost by using larger resistors, I decided to experiment with three different pairs of resistors: 10K and 1K; 100K and 10K; and 1M and 100K. I chose those values because a ratio of 10-to-1 simplifies the programming calculations that need to be made. Also, in order to maintain as much accuracy as possible, I measured the actual value of a dozen or more resistors for each of the above nominal values and paired them so the measured ratios were as close as possible to 10-to-1.

The program that I used for this experiment (*Pi_PS_Test1.bas*) is available at the article link. It's fairly straightforward and well commented, so we won't discuss it in detail. It

Pi UPS Voltage and Current Calculations

Trial	1	2	3
Top Resistor (Measured)	10.00k	99.90k	1.023M
Bottom Resistor (Measured)	1.00k	10.00k	**102.3k
Battery Voltage (ADC Calc)	11.13V	11.22V	11.27V
Battery Voltage (Measured)	11.12V	11.24V	11.30V
Voltage Calculation Error	+0.01V	-0.02V	-0.03V
Current Draw (Calculated)	1.01mA	102µA	10.4µA

** Two separate resistors were necessary to obtain this value (100.1K + 2.2k).

■ FIGURE 9. Voltage and current calculations.

simply reads the ADC value, converts it to mV, and then computes the battery voltage and displays both voltages in the terminal window.

Figure 9 shows the results that I obtained for the three different pairs of resistors. As you can see, the larger resistors did, in fact, result in larger errors in the voltage calculations. However, the 1M and 100K (nominal) pair of resistors only resulted in a 0.03V error. That's certainly acceptable for our purposes, and the significant reduction in current consumption produced by the largest pair of resistors should also result in longer battery life.

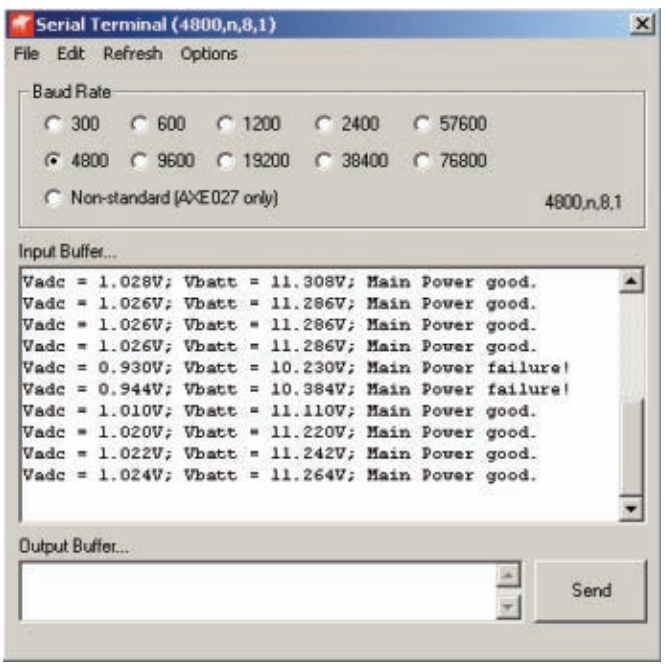
Finally, it's interesting to note the inverse relationship between battery voltage and current draw; greater currents result in lower battery voltages. We will see that effect again in our second experiment.

Experiment 2: Main Power Voltage-Sensing Circuit

In the breadboard setup of **Figure 8**, the main power voltage-sensing pin — which has already been divided down to a safe voltage level — is directly connected to pin C.3 on the 08M2 processor. As we discussed earlier, if the 12V main power supply is functioning correctly, the input pin will be in a high state.

On the other hand, if the main power supply goes down, R2 will pull the power input down to ground, so the input pin will be in a low state. The program that I used to monitor the main power supply voltage (*Pi_PS_Test2.bas*) is also available for downloading. Essentially, it's the same as the *Pi_PS_Test1.bas* program we just discussed, with the addition of a simple *if/then* statement that tests the digital voltage level at pin C.3.

Figure 10 is a screenshot of the terminal window display as the program was running. Just before the fifth line was printed, I pulled the plug on the main power supply. At that point, my Pi continued to run without interruption because the battery supply had immediately provided the necessary power. In the next two lines, the program reported the main power failure. As soon as I reconnected the main power supply, the program reported that event, as well.



■ FIGURE 10. *Pi_PS_Test2.bas* output.

The changes in the battery voltage shown in **Figure 10** are interesting to note. When the power failure initially occurred, the battery voltage immediately dropped by more than 1V. Five seconds later in the next iteration of the main loop, it had rebounded somewhat, and when I reconnected the main power supply, the battery voltage began to recover. Finally (although it isn't shown in **Figure 10**), the battery voltage soon returned to its "pre-failure" level.

At this point, you may want to download the *Pi_PS_Test2.bas* program to your breadboard setup and see whether you obtain similar results.

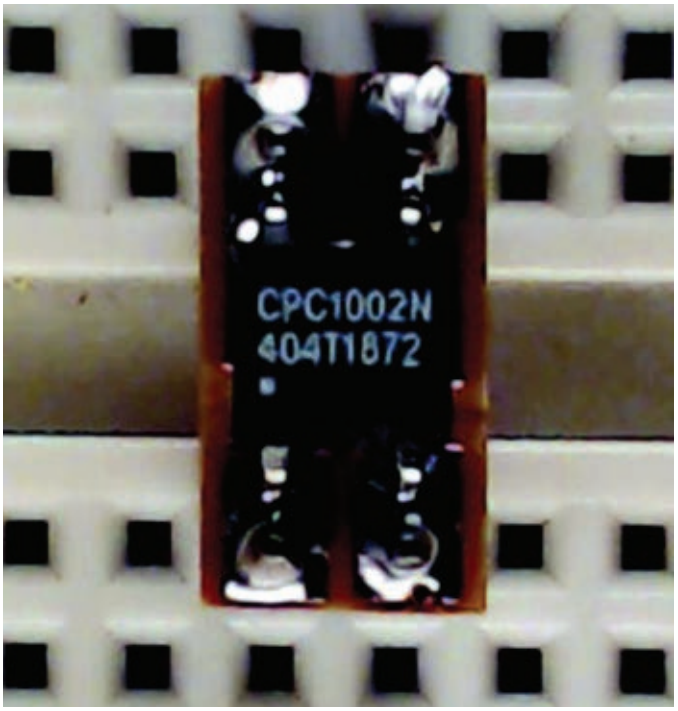
There are two more things I want to mention about our UPS project before we move on. First, even though I developed the UPS with the Pi in mind, it can easily be used for any PICAXE project that requires stable power over long periods of time. In fact, a much smaller and simpler UPS could easily supply the PICAXE's relatively small power requirements: a seven-cell AA battery pack should suffice; a much smaller heatsink (or none at all) would do the job; and there would be no need to beef up the power and ground traces on the stripboard.

Second, even though the 1M and 100K voltage divider only consumed a little over

10 µA of current, I did some additional experimentation to see if I could disconnect the voltage divider from the batteries whenever the 08M2 was not making an ADC reading — which would be about 99.99% of the time!

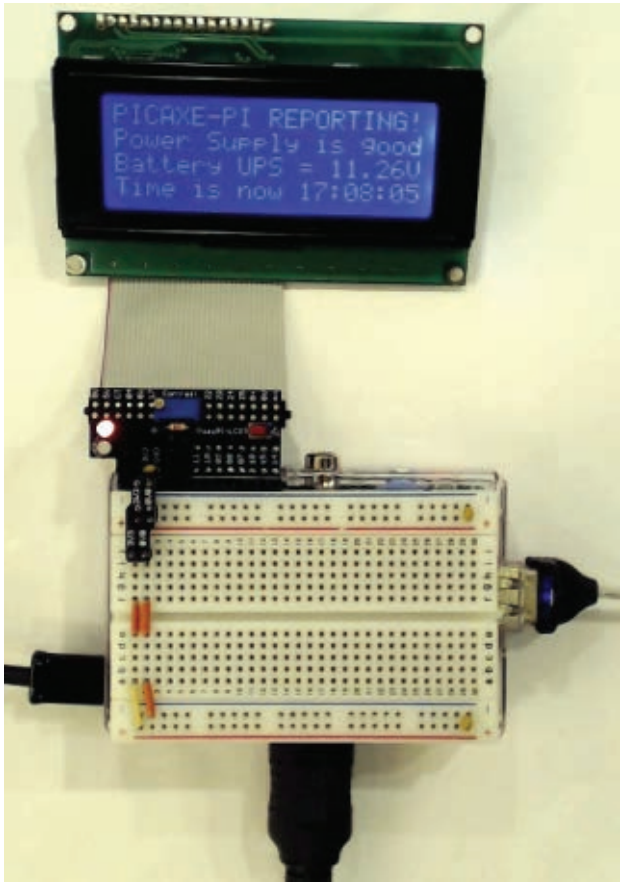
In the process, I happened upon the CPC1002N which is an SMD solid-state relay (SSR) that contains an optically coupled MOSFET transistor. The CPC1002N is capable of switching up to 700 mA of current, so it's a useful device to keep in mind. Not only for our UPS, but also for a variety of other PICAXE or Pi projects.

Figure 11 presents a close-up photo of a CPC1002N that I soldered to a small scrap of stripboard and inserted into a breadboard. I added the CPC1002N to my breadboard circuit for the UPS and was easily able to control the connection to the voltage divider circuit. When the SSR was open (99.99% of the time), there was no measurable current flow through the resistors. Whenever the program temporarily closed the SSR and measured the ADC voltage of the battery pack, the results were in line with our earlier results. So, I decided to keep the CPC1002N in my UPS circuit.

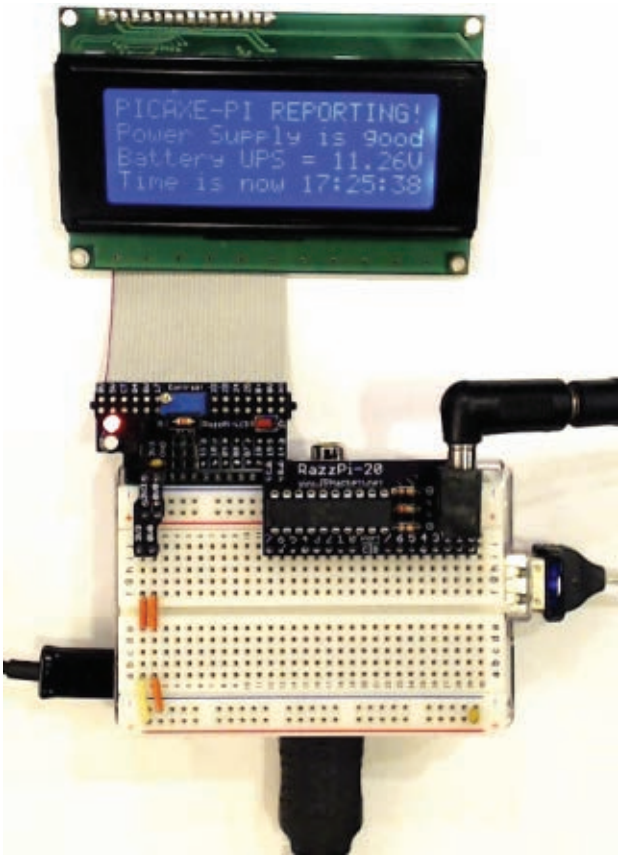


■ FIGURE 11. CPC1002N SSR on breadboard.

We don't have enough space left this month to discuss the CPC1002N in more detail, but if you want to experiment with it, it's



■ FIGURE 12. RazzPi-LCD board.



■ FIGURE 13. RazzPi-LCD and RazzPi-20 boards.

available on my website (**www.JRHackett.net**) as is the datasheet.

PCB Update

For the past few months, I've been working on several different PICAXE-Pi PCBs — two of which will be available on my website by the time you read this article. The first one — the RazzPi-LCD board — is shown in **Figure 12**. It inserts directly into the Pi's 2x13 GPIO header and provides access to all 17 GPIO pins: six for the LCD; 10 for the breadboard that sits on top of the Pi's plastic case; and one for an onboard pushbutton switch.

The RazzPi-LCD board simplifies the breadboard wiring because wire jumpers can easily be used to connect any of the 10 available GPIO pins directly to the breadboard circuit. However, you can also use the second board (RazzPi-20) in conjunction with RazzPi-LCD as shown in **Figure 13**.

The RazzPi-20 board accepts either a 20M2 or 20X2 PICAXE processor. Two of the processor's I/O pins are inserted into the Pi GPIO pins 14 and 15, so the PICAXE can communicate serially with the Pi without any additional wiring. If you're interested in either of these boards, you can visit my website for more details.

Another Request for Feedback

We've reached the end of the sixth Primer installment that's been dedicated to PICAXE-Pi projects. Before we embarked on this little side journey, I asked for some email feedback to let me know whether there was a significant interest in exploring the PICAXE-Pi possibilities. A surprising number of readers said "yes," so that's what we did. Now that a year has passed, I think it's time for me to again ask for feedback, so here are my questions:

- What would you like to see in upcoming columns?
- Do you want to continue our PICAXE-Pi explorations?
- Would you rather intermix the Pi coverage with some PICAXE projects?
- Or, have you had enough Pi for now, and want to return to pure PICAXE?

Whatever you think we should do, please email me at Ron@JRHackett.net and let me know. In the meantime, have fun! **NV**

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■ BY LOU FRENZEL W5LEF

The Internet of Things and Machine-to-Machine Communications Emerge as Internet Drivers

In case you haven't heard, the Internet of Things (IoT) and Machine-to-Machine (M2M) are the next big things in Internet growth and new communications applications. Both technologies are expected to enable billions of new devices in the coming years. Now, you can do things like control your slow-cooker crock pot from your iPhone over the Internet and similar *(Figure 1)*.

WHAT ARE IOT AND M2M?

IoT and M2M are essentially the same thing but slightly different in applications. Both are communications technologies that are used to monitor and/or control practically any device by way of a link including the Internet. M2M came first as a technology for business, industry, and commercial use in monitoring fleet vehicles, pipelines, vending machines, and similar objects. In effect, M2M is just a modern form of telemetry.

IoT or the Internet of Everything (IoE) as some call it is just an extended form of M2M that not only includes machine-to-machine communications but also machine-to-human or human-to-machine. IoT is what you might call M2M for consumers. In any case, there are no formal definitions. One key distinction is that M2M applications are usually more highly managed than IoT because of critical needs in business and industry.

While the IoT and M2M movements are just beginning, many in industry predict that from 20 to 100 billion devices could possibly be connected by 2018 or 2020. Chances are by then you will probably own one, if you don't already.

THE PROCESS

Picture this. In most M2M and IoT cases, the device to be monitored or controlled has an integrated sensor and wireless transceiver that may connect via the cellular system, Wi-Fi, or other wireless link to the Internet. Cellular links connect directly to the Internet, while Wi-Fi or other wireless technologies connect through a

■ **FIGURE 1.** The crock pot from Belkin is called a WeMo device. It uses Wi-Fi and a smartphone app to control cooking via the Internet.

Go to **www.nutsvolts.com/index.php?/magazine/article/june2014_OpenComm** to comment on this article.

■ **FIGURE 2.** The Google Nest thermostat learns normal use patterns and can be controlled over the Internet by way of a Wi-Fi connection to a home router.

gateway that connects to the Internet. The Internet connection contacts a remote server that contains the application software. Then, the monitoring device (like a laptop, tablet, or smartphone) makes an Internet connection to the server to complete the service. Data is then captured and displayed, stored, or some control commands are issued. All devices are assigned an Internet Protocol (IP) address.

APPLICATIONS GALORE

One of the earliest applications of M2M was to monitor the location and condition of trucks and fleet cars. These vehicles were equipped with GPS receivers that transmitted the location back to a central office for tracking. Other assets like freight cars, pallets, or containers can be tracked in a similar way.

Monitoring remote facilities is another key M2M application. Companies want to keep informed of the status of their tank farms, pipelines, oil rigs, and other unmanned locations. Almost any communications link in industrial automation systems in factories can be considered M2M. Security systems (including video surveillance) use M2M to stay connected.

One major new M2M application is monitoring the smart grid. This includes monitoring electrical generating plants, electric substations, and the interconnecting lines. It also includes remote meter reading. Many homes are now equipped with smart meters that monitor energy usage and report it back to the utility via a wireless connection. Point of sale (POS) terminals used in retail are also a major use of M2M.

As for IoT applications, it is hard to know where to start. Appliances like the crock pot mentioned earlier are only one example. While your toaster and blender probably won't be connected, other major appliances will be. Already, some washing machines, dryers, and dishwashers have wireless links to report their usage and condition back to the manufacturer.

A popular IoT item is the home thermostat. With built-in wireless and Internet connectivity, the thermostat can be controlled remotely with a laptop, tablet, or smartphone. One popular product is Google's Nest thermostat in **Figure 2**. The home HVAC can be turned off or on, or its temperature can be set remotely from anywhere in the world with an Internet connection. Home lighting is another typical utilization of IoT. You can remotely turn lights off or on, dim them, or (in the case of some new LED lighting systems) change colors. A remotely operated door lock and garage door opener are other examples. Any home device or system is a potential target for IoT.

Medical and fitness devices are also examples of IoT. There are wireless heart rate monitors and pedometers for runners, cyclists, and other athletes. For medical patients, there are wireless blood pressure, blood glucose, temperature, electrocardiogram, and other monitors that can be read via an Internet connection. These sensors have wireless capability and report to a gateway that sends the data off to a monitoring station where a doctor or nurse can interact as needed.

A forthcoming IoT application is wearables. The new smartwatches are an example (**Figure 3**). All sorts of wearable devices from watches, glasses, gloves, vests, and others will generate data and transmit it wirelessly. No telling what new applications or capabilities will come out of this.

One huge growing M2M niche is telematics. Telematics is the wireless technology associated with the automotive industry. Some existing M2M applications are hands-free Bluetooth connections for cell phones and in-car Wi-Fi hot spots that link to the Internet via a cellular connection, but that's just the beginning. Coming soon are more sophisticated services, such as vehicle- to-vehicle (V2V) communications that will connect one vehicle to others nearby. The goal is to avoid collisions. Each car or truck will announce its location via GPS, its speed, and direction.

■ **FIGURE 3.** This Samsung Gear is an example of a wearable device. It communicates by way of Bluetooth to a smartphone.

Embedded micros in each vehicle will analyze the data and provide feedback to the driver. Even automatic braking can be deployed in close-call situations.

Then, there is vehicle-to-infrastructure (V2I) systems that let vehicles communicate to nearby roadside nodes in a network that can supply traffic, weather, road conditions, and other safety information automatically. These services will use a Wi-Fi type of wireless technology called Dedicated Short Range Communications (DSRC) in the 5.9 GHz band for communications. The Department of Transportation's National Highway Traffic Safety Administration (NHTSA) believes that up to 80% of all collisions could be avoided with such systems. Look for them to become standard on vehicles in the future.

> While the IoT and M2M movements are just beginning, many in industry predict that from 20 to 100 billion devices could possibly be connected by 2018 or 2020.

WHAT WIRELESS WORKS FOR M2M AND IOT?

Almost any short-range wireless technology will work for M2M or IoT, but some common ones are emerging. For example, cellular connections make up about 40% of all M2M applications. A cellular modem module like that in **Figure 4** is embedded into the device to be monitored. An accompanying embedded microcontroller runs the applications. Older 2G technology like GSM and GPRS cellular can be used, but with some carriers planning to phase out the older GSM 2G networks it makes GSM and other older methods a poor choice. Most new systems will use the faster 3G WCDMA and 4G (LTE) cellular modems despite the fact that most M2M applications require mostly low speed (<500 kbps) data rates. Most of the major cellular carriers like AT&T, Sprint, T-Mobile, and Verizon offer M2M services.

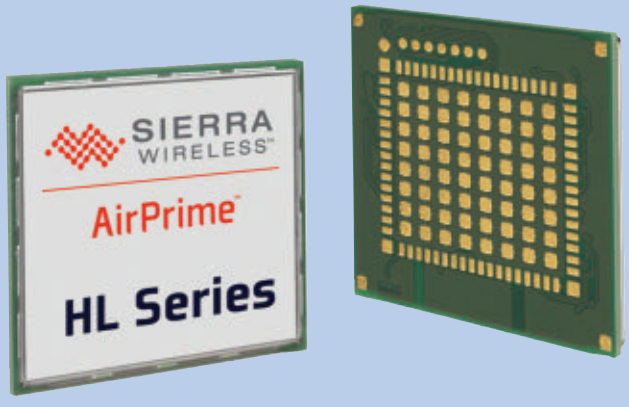
Wi-Fi is another popular connection technology. Since it is available in millions of hot spots and home networks everywhere, it is a likely choice for IoT. Wi-Fi modules are easy to build into most products. The 802.11n standard in the 2.4 GHz band is probably the most common, but high speed overkill for most slow IoT apps. It is not too likely that the new faster 802.11ac standard in the 5 GHz band will see IoT service unless the application demands speeds to 1 Gbps.

Bluetooth is another IoT choice. It is the favored wireless technology for portable devices like fitness, medical, and wearable items. Bluetooth's low energy version draws little power so is a good match for battery-powered devices.

ZigBee is another good option, especially for home networking, smart metering, and sensor networks. The ZigBee mesh capability lets you monitor hundreds (even thousands) of connections. A variation of the IEEE 802.15.4 standard upon which ZigBee is based could be used without the mesh capability. One potential option is 6LoWPAN which is a modified version of 802.15.4 that encapsulates a compressed header for an IPv6 address. It's ideal for all these billions of devices.

All sorts of other wireless technologies could be adapted to M2M and IoT. Some possible alternatives are Dust Networks WirelessHART, ISA 100a, and Z-Wave. Even the TV white space wireless systems offer a longer range option. For really short-range applications (less than a foot), you could use RFID or Near Field Communications (NFC).

Incidentally, neither M2M or IoT have to be wireless. If a wired connection is available, it can be used. In some original M2M applications, a dial-up telephone connection using an embedded modem chip was a common solution. Any wired network is a possibility. Ethernet and fiber optic links are options, as well as power line communications (PLC) that transmit data over the AC power lines. Several PLC variations are available including HomePlug, IEEE 1901, G3, and PRIME.



■ **FIGURE 4.** This cellular module by Sierra Wireless is only about one inch square but houses a complete GSM/GPRS/HSPA cellular modem with internal GPS/GLONASS receiver for embedding in an M2M device.

STANDARDS PROGRESS

One issue possibly slowing adoption and development of M2M and IoT are the lack of standards. Standards define not only the wireless technology but the access methods and protocols. The protocols state how the data is packaged and transmitted. Standards are also agreed upon to permit interoperability of products for different manufacturers. Interoperability may not be a problem, but comfort will come to

developers who want some design guidelines and to manufacturers who would like some specifications to build and test to. While no formal standards exist, there are multiple efforts underway.

For example, the International Telecommunications Union (ITU) is developing some M2M standards but these will not be available for a while. The Telecommunications Industry Association (TIA) is working on its TR-50 standard that could be completed by the end of the year.

Another effort is the work of AllJoyn Alliance that is using the previous work of Qualcomm to create some standards based on the Linux OS. The Internet Engineering Task Force (ITEF) 6LoWPAN is also in the running as a standard. IBM, Intel, and Cisco have done some standards work, as well. Finally, a new organization called the Industrial Internet Consortium (IIC) is beginning standards work.

SOME THINGS TO CONSIDER

It is interesting to see the immense interest in M2M and IoT. However, some are unsure of the security and safety of the data being communicated. This problem could limit IoT adoption in some critical applications. While most wireless technologies incorporate heavy duty encryption, other forms of security like authentication or the use of VPNs may be necessary for some applications. Each system will require its own solution.

Another issue is the potential for massive electromagnetic interference (EMI) problems. Just imagine all the noise and interference of billions of low power radios all working at the same time. We are not at the point where this is an immediate issue, but it is one to contemplate.

M2M and IoT are the technologies of the year. Look for increased adoption in the future, and get ready to participate. **NV**

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These micro gearmotors have a 3 mm D-shaft that protrudes from the gearbox case. ServoCity has several compatible accessories including pinion gears, hubs, and couplers that attach directly to the shaft. There are nine different RPMs to choose from. Pricing is US$9.99 each.

CHANNEL MOUNT GEARBOX

The SPG785A-CM servo power gearbox also from ServoCity utilizes the Hitec HS-785HB sail winch servo (included) to create a high-torque servo power gearbox. The stock Hitec servo can rotate several turns in factory form (approximately four turns on most Tx/Rx systems; up to eight turns with a 650-2,350 usec signal).

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ECONOMICAL 7" 500 MHz TOUCH PANEL PC

Saelig Company, Inc., is now offering the GK-7000 Touch Panel PC to provide commercial customers with a rugged industrial control panel that is attractively housed, has multiple I/O connections, and is simple to install. Running Windows CE 6.0 and featuring an optional built-in rechargeable battery, the GK-7000 is ideal for embedded applications in environments where power is intermittent. Not only will customers appreciate the reliability and functionality of the GK-7000 but the price point is highly competitive, greatly reducing the total cost of an embedded computing project.

The GK-7000's 7" 800 x 480 TFT color display features a four-wire resistive touch panel. The GK-7000 is a high performance embedded controller which features a Samsung ARM-based S3C2416 processor with Microsoft's Windows CE 6.0 operating system. With the built-in 32-bit 500 MHz processor, the unit can be powered from regulated 9V-12V, with consumption at an extremely low eight watts. The GK-7000's features of rugged design, multiple interfaces, low consumption, and high reliability allows designers to appreciate its functionality, as well as recognize the highly competitive pricing that makes adding an HMI feature to a product affordable.

Built-in interfaces in the GK-7000 Touch Panel PC include: USB1.0 x 3; USB2.0 x 1; RS-232; RS485; SD slot (for up to 8 GB memory); 10/100 Ethernet mouse/keyboard support; and built-in speaker for audio output. Optional extras include: 802.11 b/g Wi-Fi; GSM/GPRS; Bluetooth; VESA 75 mm rail mount; and a 2,000 mAh battery. With compact dimensions of 7.9" x 6.0" x 2.0" and a light weight (1.14 lb without battery; 1.34 lb with battery), the GK-7000 will see use in a variety of equipment design areas. The GK-7000 is ideal for applications in the vehicle, service, or retail industries, industrial machine operation, video conferencing, or point-of-sale kiosks. The GK-7000 is designed for an operating temperature range -4°F to +140°F. The GK-7000 is manufactured by Lilliput Electronics Co., Ltd.

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Continued on page 41

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COMPARE & SAVE

 Continued from page 7

schools throughout the US for 'fire insulation.' Now, it's a big problem. I'm with you — err on the side of caution until someone figures out what's going on. Certainly, the manufacturers aren't publicizing this information.

Bryan Bergeron

Potential Burnout

I'm writing about "The Decade Box Revisited," by Frank Muratore in the April 2014 issue. This circuit is similar to one published in *Nuts & Volts* by Fred Blechman about 10 or 12 years ago.

However, I believe Mr. Muratore's circuit arrangement is a little better than Fred's was.

Frank mentions the possibility of burnout if a 10-turn potentiometer is used. This is also possible, though not as likely in the circuit printed. The specified pots — according to the 2013 Parts Express catalog — are rated at 1/4 watt.

The power rating is much lower when the pot is set to a low resistance, and can result in pot burnout (I know from experience). I have two suggestions to reduce the chance of burnout. First, connect a 1/2 watt resistor — 10% of the resistance of the pot — in series with each pot.

Second, consider the use of higher power pots, especially for 100 ohms and 1,000 ohms. Pots with a two watt rating are available at a higher cost.

Bill Stiles

Definitely a 'retro' article. An experiment really. I had a similar box 30 years ago.

In any event, your catches are right on target. Great mods.

Bryan Bergeron

Points to Consider

There are some discrepancies in the April 2014 BaTESLA article:

1. C1 is listed in the Parts List as a high voltage cap, but C4 is referenced in the write-up (p. 26).

2. A five foot CFL is referred to on p. 27. Where could I purchase that?

3. The use of the term "winding" to describe one turn around the form is not common in electronics (see p. 22, et al.).

4. The Parts List would be much more useful if manufacturer's part numbers were listed.

5. The use of the term "metric" on p. 23 to mean parameter is out of place in DIY electronics.

6. It would be a great help if the schematic had parts values on it.

7. Use of the power rectifier BR1 at RF frequencies might better be served by four lower capacitance high-speed switching diodes. Likewise, use of an electrolytic capacitor at RF (C3) is not necessarily going to produce good results unless a low inductance capacitor is paralleled with it.

8. The external DC input referenced on p. 24 doesn't seem to be on the schematic as such. There is a TP there, but that's not usually considered to be an auxiliary input connection — especially since there's no polarity indicated nor another connection for the other power supply connection.

9. What is a "rectified input jack" referenced on p. 24?

10. How is the "programming port" used?

Phillip Milks

I have addressed each of Phillip's points below:

1. The C4 reference on p. 26 is a typo and should read "C1." C1 Is listed as a "1 µF metalized polypropylene capacitor" in the parts and does not have a voltage designation. The article points out that it must withstand the high voltages developed. A good source for this type of capacitor is from the circuit boards of obsolete CRT monitors. It is possible to use multiple 250V or 800V caps.

2. This is obviously a typo and should read "five foot FL (FLUORESCENT)":

3. I'm not sure how the term "WINDING" does not properly describe something that is "WOUND" on some type of form.

4. I agree.

5. I am not sure how this is a discrepancy.

6. I am not sure how this is a discrepancy.

7. Any type of diode rectifier circuit that can be quickly charged/discharged will work. Feel free to use any type of diode/capacitor combination you have on hand for this circuit.

8. This is a typo and should have read "external AC source." It should have been deleted from the article since I did not include an external power jack in the schematic.

9. See previous answer.

10. The programming port is the three-terminal audio jack that connects Serial In, Serial Out, and GND to the PIC for programming it in place (audio jacks are the most common type interface for PICAXE). This connection to the programmer is not necessary if you program the PIC outside the circuit. Most micros use an FTDI converter for USB to RS-232. The DATA(+) and DATA(-) become Rx/Tx which connect to the serial pins on the MCU. The Tx connects to the Serial In and the Rx connects to the Serial Out pin.

Matt Bates

Smiling About Arduinos

I'm reading Smiley's Arduino series and plodding along. Getting better daily. Well done, Mr. Pardue!

Bill Pointon WA2CG

Love That Pi!

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Altaire computers, E-Games, DIY PCs, Internet, embedded microcontrollers, and recently the Raspberry Pi.

Having lived through all of this (at 64), I thought I saw it all until your magazine featured articles on Raspberry Pi!

I bought two and I am having a great time working with them using your articles. Hats off to Hackett, Kibalo, and Lindley.

William K.

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A 150 MHz RF SIGNAL GENERATOR FOR YOUR TEST BENCH

By Robert Reed
rjr@ncweb.com

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com /index.php?/magazine/ article/june2014_Reed.**

Once our interest in electronics is piqued, our inventory starts to grow — first in knowledge gained by books and select articles, followed by a small inventory of parts, and a few pieces of basic test equipment. We usually start with a simple DMM and some sort of power source. As time goes by, we accumulate a fair amount of basic equipment. However, no test bench is complete until it has an RF signal source of some type. What I will present here is a sweet little general-purpose RF signal generator that won't take up much bench space, will fill that missing gap, and can be built fairly cheaply.

Let me start with a brief overview of what's out there. Signal generators come in a wide variety of flavors. Starting at the very top end would be a generator that oscillates at only one frequency that is extremely accurate, such as might be used by NIST (National Institute of Standards). These are primary frequency standards and time bases by which all other frequencies are referenced to. They have incredible accuracy and can cost upwards of $100,000. Next in line would be very high-end generators with super specs of accuracy and stability, along with any type of modulation that's available. Today, these mods can be quite complex. Then, we drop down to mid-range generators that — although they still have excellent specifications — will be more application-specific (limited frequency bands, etc.) rather than "all purpose." Many of these are slow in use due to programming and a myriad of pushbuttons. Once you pick your chosen frequency, they perform excellently, but they can cost anywhere from $1000s to $10,000s.

One corporation I worked for involved using a very complex microwave generator which had excellent specs in a myriad of features and — although you could perform just about any frequency related test with it — it was also slow to get to each specific point of interest. The user manual was a full 3" thick and it would probably take a year to become totally proficient at using this generator. One other thing was that it reportedly came with a $38,000 price tag.

At the very bottom of the heap is the general-purpose generator which may run from $200 upward. These are basically intended for

consumer product service and non-critical design work. Although they lack the features and quality of higher-end generators, they have several glaring advantages: ease of use, the speed to run the gamut of their entire output range, plus (the biggest merit) very low cost. No array of pushbuttons or programming here. Just flip a switch, turn a knob, and rapidly get to where you want to go. Their intended market is directed at ham operators, hobbyists, or people that like to tinker with electronics which would be people just like us. Having tried several commercial general-purpose generators over the years, I felt that better performance could be achieved which set the stage for designing one from scratch. These generators were priced in the $180 to $250 range.

The one I am presenting in this article will have superior performance in all specs and (assuming the builder has a moderate junk box of components) can be built for about $50. This does not include a commercial housing, which at a minimum would cost $75 and up. As I will explain later in this article, there is a procedure for forming your own.

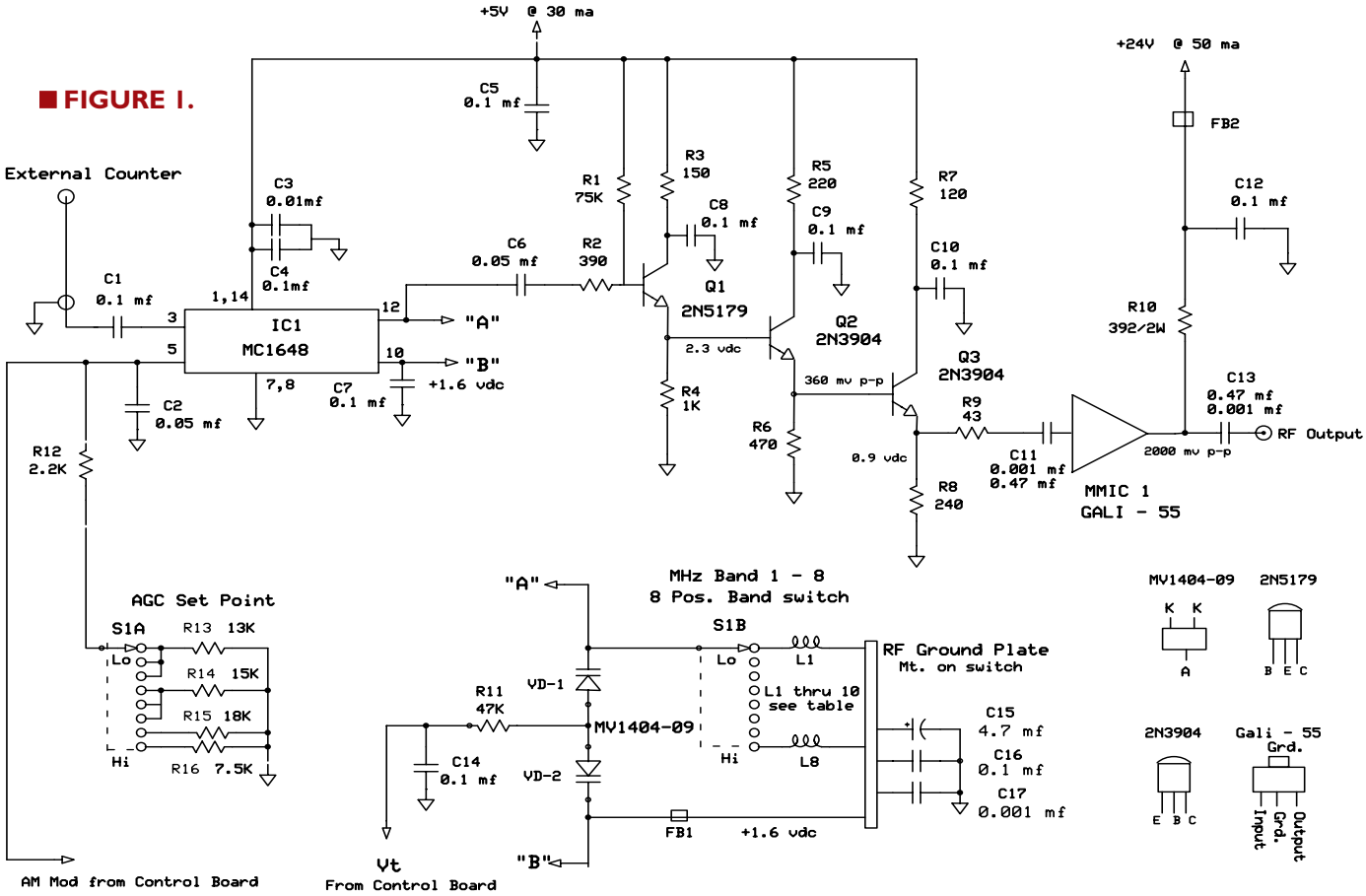
Theory of Operation

The heart of this unit is the RF deck. If you read my article in the December 2013 issue (180 MHz Sweep Generator), you will see a very similar design here. I covered the theory of this section quite thoroughly in that article, so I won't dwell on it too much now. I have used this style in seven or eight different designs over the years, which ran the gamut of simple one frequency oscillators to complex phase lock loop synthesizers, and it has always been a solid performer.

To begin with and referring to **Figure 1,** the RF deck is based on a marvelous chip developed by Motorola in the early '70s. (So popular, in fact, that it is still being produced today — almost 40 years later!) The IC is a MC1648 DIP. However, current versions are in SMD form and go by the name of MC100EL 1648, but are still available in the DIP version. This chip is a member of the ECL (emitter coupled logic) family and is basically a high speed LC oscillator circuit. It can cover a large range of frequencies from MF, HF, and well into VHF portions of the RF spectrum. It is easy to use and has built-in AGC (automatic gain control) that can be tailored to your particular needs.

In this design, various resistors (R13-R16) are switched in as the frequency bands are switched. The tank circuit impedance will vary over a tremendous range when a fixed capacitance tuning value is used for all bands, but by trimming the AGC bias for each range it will do an excellent job of maintaining a leveled amplitude output from the tank circuit. It also has an output buffer amplifier that I use in a non-traditional way for an external counter.

■ FIGURE 1.



The LC tank circuit is comprised of switched inductors L1-L8 and the capacitance of varactor diode VD1 and VD2 (which is actually two diodes in one package). Varactor diodes exhibit a changing PN junction capacitance with a changing DC negative bias voltage across that junction. The SMV 1404 series are of the Hyper-Abrubt type, and have the highest Tr (tuning ratio) capacitance vs. bias voltage and linearity of all the various styles of varactors. They have a Tr of 16:1 or higher, and over a one octave range of tuning which gives excellent linearity.

In my opinion, the 1404 series of varactors is the greatest varactor ever produced for projects like this since they cover MF through VHF bands of frequency. As luck would have it, they are also the most difficult to obtain.

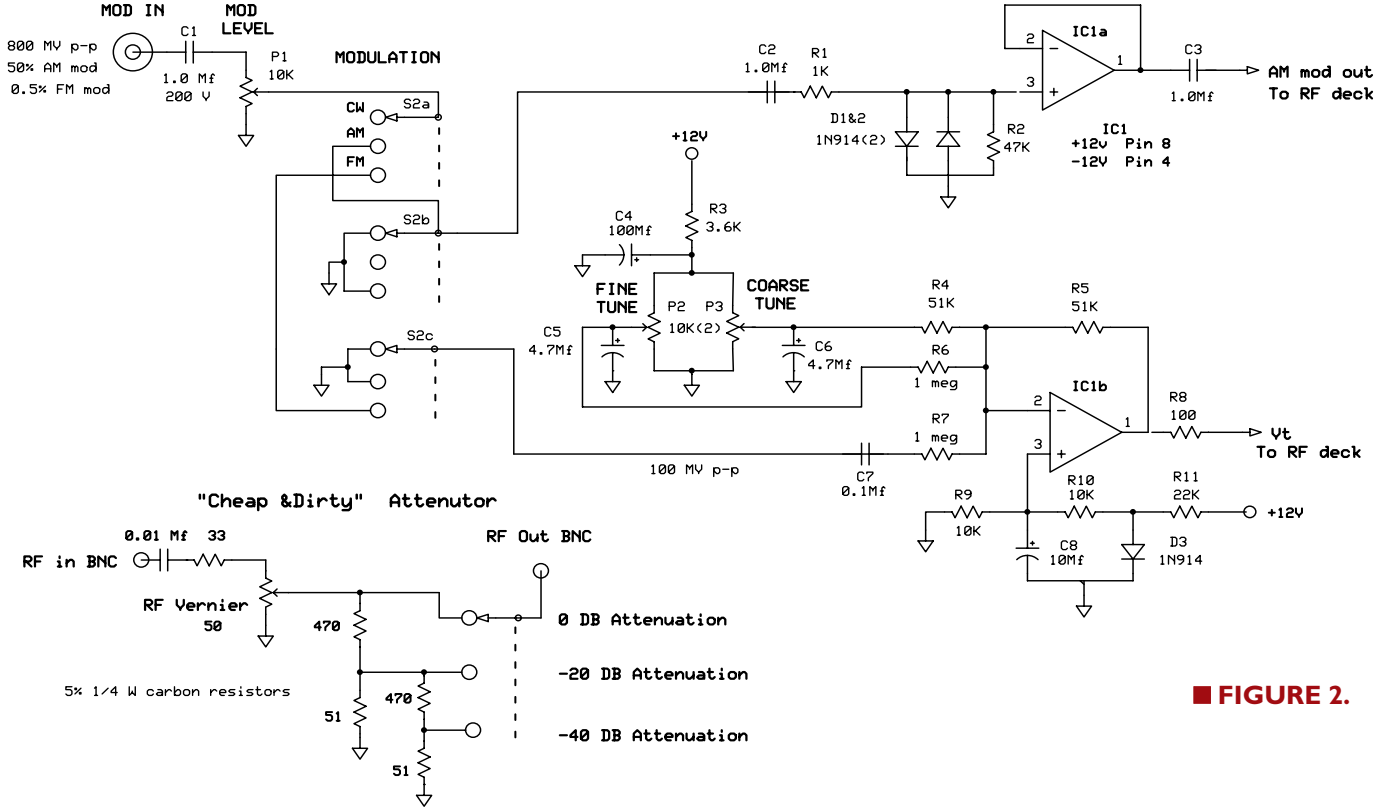
Rather than take the output from the normal amplifier port which can be somewhat distorted, I chose to take it right off of the attached LC tank circuit which has a very clean wave form, thus saving the amp port for external counting operation. By designing it in this fashion, it needs a lot of buffering from the high impedance tank circuit to the 50 ohm input of the final MMIC (monolithic microwave integrated circuit) amplifier. This is the job of Q1, Q2, and Q3. These are all cascaded emitter followers and start with Q1, which has a very low input capacitance.

Since high frequency followers with an inductive element in their base circuit can sometimes be unpredictable and break into oscillation, a "stopper resistor" R2 was added in series to the base input. This has the effect of dropping the "Q" of that area's parasitic elements, and ensures that any parasitic oscillations will not occur. Q2 adds yet more buffering, and Q3 is configured to drive the final amplifier (MMIC 1). With the addition of R9, this gives a good 50 ohm impedance match which is required here.

The MMIC amplifier is of a family of ICs known as gain blocks. Their input and output impedance is always 50 ohms, and they have a fixed gain with no control over that function other than adding attenuators to adjust the input or output level. This particular one has a 20 dB gain (X10 voltage) and is very flat from DC to well into the GHz range. The drawback of having no internal gain control is completely overshadowed by their utter simplicity: Just solder it in and go!

FB1 and FB2 are ferrite beads that "gobble up" any high frequency components on those leads as we want to keep these wires very quiet. The GALI-55 amp wants to see a 50 mA constant current supplied to it rather than a constant voltage (approx. 4.5 VDC). You might be wondering why I designed its power source the way it is shown, which is quite inefficient to supply 50 mA to a low voltage device. It all has to do with bandwidth ratio and not just merely bandwidth.

If I were designing a generator for, say, an output of 1 GHz to 1.15 GHz, that would still require a bandwidth of 150 MHz. However, I could then use one RF choke for the load and it would remain relatively constant over that ratio of change. This would only require a five volt feed to power



■ FIGURE 2.

the MMIC at 50 mA due to the very low DC drop in that choke. Even though I am covering the same bandwidth with the presented signal generator, that method would not work. The reason: bandwidth ratio.

The higher speed generator has a ratio of 1.15:1, and one choke would present a constant load over that range. My generator has a ratio of 500:1 (0.3-150 MHz). No single choke could even come close to presenting a constant load over that kind of range. So, I am committed to a resistive load for consistency over the complete range.

Doing some math, I determined that the optimum value of approximately 392 ohms is as low as I would want to go. Carrying this further, 392 ohms/50 mA = 19.6V and adding another 4.4 volts across the MMIC results in the necessity for a 24 VDC supply. Wasteful, yes, but that is one of the prices you pay for a wide bandwith ratio amplifier. The manufacturer highly recommends that you *do not* use a constant current supply in this circuit.

Figure 2 is the control circuit and front panel controls which are pretty simple and straightforward. IC1a drives the MC1648 AGC pin 5 directly for AM modulation. Being a follower type of configuration, its amplitude will remain constant despite changing loads due to the AGC section of the band switch presenting different loads depending on its location. Diodes D1 and D2 clamp the input signal circuit for a maximum signal level of 1.4 volts P-P. This is for the protection of over-driving P5 of the MC1648.

R1 limits the current during periods of heavy clamping. The external AM signal is fed into the mod input jack to P1 level control and through modulation switch S2 when in the AM position. For FM modulation, the signal is brought in through the same path other than the S2 switch position. From there, it goes into IC1b's summing point. When no modulation is desired, S2 is set at the CW position (Continuous Wave) and mod input capacitors C2 and C7 are grounded to keep these lines quiet.

IC1b has several functions: It sums all the voltage inputs of the coarse tune control, the fine-tune control, and the FM mod input (when used). Op-amp summers are nice for this type of adding as there is absolutely no interaction between the inputs feeding it. As can be seen, the tuning controls are well filtered to keep this line as quiet as possible. The output of IC1b requires a 100 ohm resistor R8 in series with it due to the necessity of driving a large filter capacitance when entering the Vt connection on the RF board. Op-amps can become unstable, driving large cap loads; R8 is the cure for this. Since the tuning span Vt has to cover a range of -6.1 volts to +0.6 volts, an offset in the op-amp output of +0.6V is needed for its starting point. This is accomplished with R9, R10, R11, and D3 at its positive input.

D3 provides a convenient source of 0.6V, but also performs one other function. It has a PN junction drop of 2 mV/degree C which is the exact opposite to the tank circuit varactor diode Vd1, Vd2. This helps to stabilize the oscillator frequency in that respect (ambient temperature) by putting a slight shift in Vt vs. temperature. It's not perfect, but helps.

The power supply shown in **Figure 3** is pretty straightforward and does not need much explanation. It might look like overkill, but was the best I could come up with considering the variety of voltage sources required. When it comes to op-amp design, I am a big fan of split supplies. The 5V supply has the capability of supplying much more current than what is needed for the RF deck, but I beefed it up to cover the counter and prescaler options. It could also be used to supply a rear panel jack for powering add-on outboard circuits. Also, I split up the 5V through two different regulators to minimize interference on the supply lines feeding the analog portion (RF deck) and the digital portion (counter, etc.).

Construction

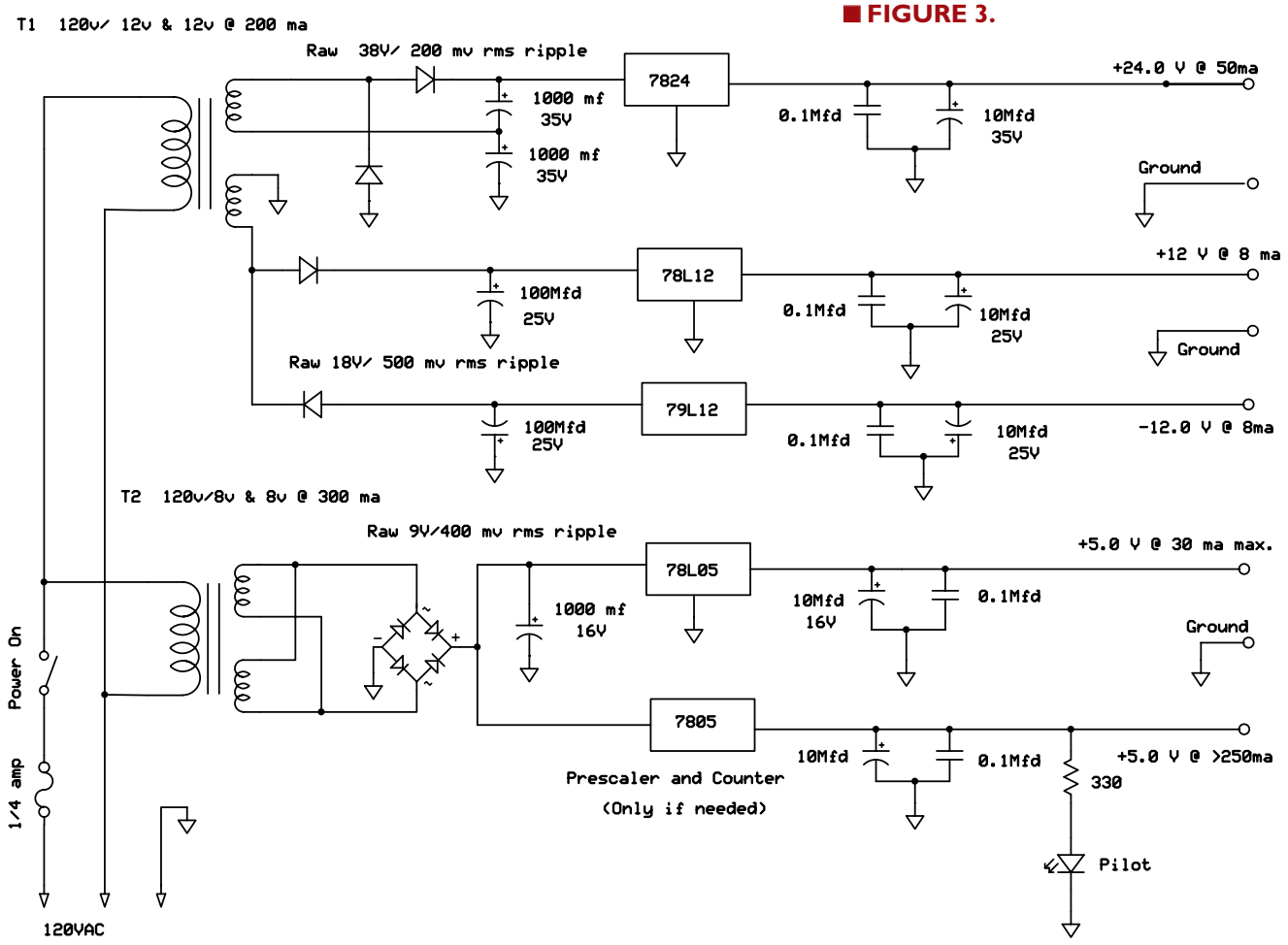
Before I get too far into this section, I will not go into a lot of details in all aspects of construction as it would take too much magazine space to discuss everything involved. Fear not, though, for those that desire to build this generator, I have a huge packet of info that I can email to you. This will include full screen pictures, actual size drilling templates, detailed layouts, construction tips, some artwork, and lots of technical data.

There are just two basic subassemblies that will be installed in this chassis: the RF deck and the power supply deck. The control circuitry is so minimal, I built it up on a small printed circuit board (PCB) and screwed it down to the power supply board. This simplifies assembly and testing before each unit is permanently installed.

The RF deck shown in **Figure 4** was built on a 2" x 2-1/2" single-sided PCB using typical RF prototype construction. The MC1648 and R1, Q1, Q2, and Q3 are the only components mounted on the laminate side of the board. Be sure to use a socket for the IC. Since only eight pins are used in this 14-pin chip, seven pins can be removed before installing it. These are conveniently located as every other pin and makes soldering underside components a lot easier. After drilling all the lead through holes, all but the ground lead holes are reamed out with a larger drill of about 5/32" to give clearance from the lead to copper foil. The GALI-55 will require two small islands for input and output connections. The SMV1404 varactor is quite small and despite SMD soldering, I found an easy way to install them.

I first cut a piece of plastic laminate (formica, etc.) to 3/8" x 1/4" and then tack the varactor to the laminate with a spot of super glue. Make sure the varactor is positioned laying on its back with its "feet" pointing up as this makes final soldering easier. This assembly is one of the last components I install, and again a dab of glue helps to adhere it to the PCB. When all leads that go to this device are soldered to their proper nodes, cut the free end to the exact length; then, a quick tack solder to the chip pins

■ **FIGURE 3.**



completes installation. I use #24 or #26 wire here.

The rest of the active components are inserted and their leads are used as solder tie points. All other circuit nodes above ground get soldered to insulated standoffs. The two standoffs (A and B) near the MC1648 pins 10 and 12 will be used for primary testing and final S1 band switch connection. When doing RF circuit construction, always keep two things in mind: an RF ground plane is essential and lead lengths must be short. How short? Well, RF design engineers have an old saying, "if you can see the leads, they are too long." Impossible in the real world, but you get the idea. The PCB is mounted to a subchassis with three 1/2" metal standoffs. This chassis will include a 3/8" hole in its vertical section to mount the band switch. Set this sub-assembly aside for now; further testing will be done later.

The RF band switch (S1) shown in **Figure 5** is a two-pole eight-position wafer switch. I used an old ceramic Centra-Lab 4 deck wafer switch that I had on hand. All decks are held in place with long #4-40 screws and spacers. These switches are easy to disassemble and rework. All wafers have a full 12 positions on them, and one metal bracket with bending tabs is used to lock the stop for the actual number of positions desired.

The number of decks on the switch does not matter, but you need at least two decks. Unnecessary decks are discarded, and the wafer shaft gets cut back so it only drives two wafers. Since the tank circuit coils on the RF deck have +1.6 VDC of bias voltage on them, we need an RF ground on their low side which has to be isolated from DC. This is accomplished by cutting a piece of single-sided circuit board to the approximate shape of the switch wafer. This is then aligned with the wafer, and the position tabs and mounting bolt locations are then transferred to the ground plate.

Since there are no moving parts involved here, the plate requires no drive shaft connection. The mounting holes will be drilled for #4-40 clearance and the coil lead holes will be about 0.050". The ground plate will be mounted with the foil side to the rear. When ready to install the coils, one end is slid through the switch's position tab as far as it will go, then the other end trimmed to allow it to pass through the ground plate. Center the coil and solder, and trim the overhanging ends.

When purchasing your switch, there are several things to keep an eye on. Look for mounting bolt construction and a full 12 position tabs on each deck. Also look for the least amount of metal brackets that seem unnecessary. The number of decks is unimportant just as long as it has at least two as mentioned, because the switch will ultimately be

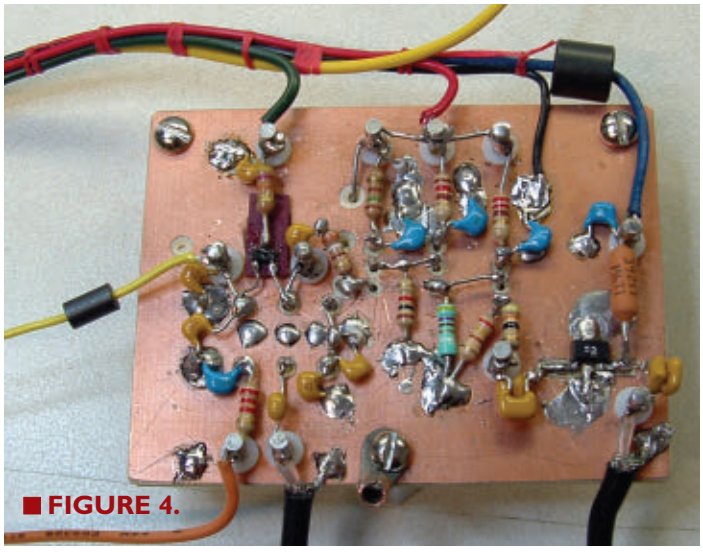
reworked to have two switched wafers (S1A and S1B) and one ground plate. The switch then needs to end up with two wafers set for eight positions by adjusting its position tab plate; the shaft cut back to a length long enough to operate these wafers if necessary; and two #4-40 bolt and spacers to hold the whole thing together.

Since #4-40 bolts are hard to find in longer than 2″ lengths, you can use threaded rod if necessary. I needed two 1/8″ lengths on my switch, and a trip to the local hardware store found the threaded rod. Again, set the completed switch aside for now.

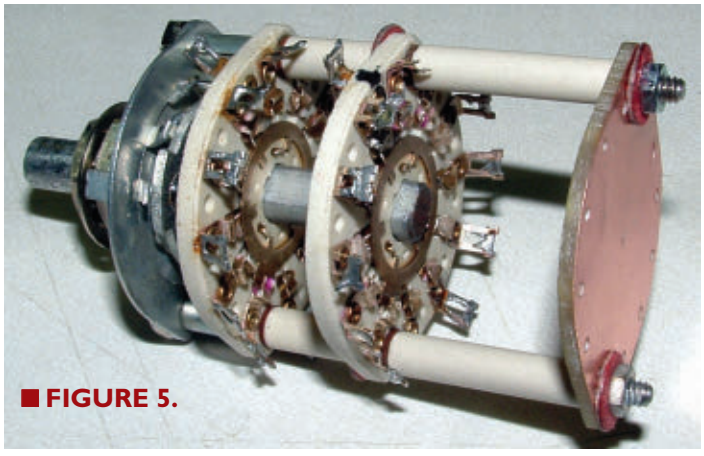
The power supply/control board construction is quite straightforward and — with **Figure 3** and **Figure 7** — does not need much further explanation. I used a piece of thick laminate (formica) drilled for component lead holes after I patterned the layout. The major components were placed in the board with a dot of super glue and then point-to-point hard wiring. Ugly, yes, but it will never be seen and I have rarely had any problems with my power supplies. It would have been nice if I could have located one transformer with both high and low voltage secondaries to make it simpler, but nothing showed up when I searched.

However, I have been using Tamura transformers in quite a few of my designs lately. They come in just about any voltage/power level that one would want and are very reasonably priced. The frequency/mod control board contains almost all the components shown in **Figure 2**. Only the pots and switches are on the front panel, plus a few components that directly interconnect these parts. The mod level control (P1) shown in the Parts List is a slightly smaller version of P2 and P3, and was chosen only because its size fit better into the panel space available there.

The enclosure was formed with four pieces of aluminum sheet stock and a foot or so of aluminum 1/2″ angle. The dimensions are approximately 9″ wide x 4″ high x 6″ deep. The first piece formed was the cover. Then, all other pieces were cut to fit which are: the front panel, rear panel, and bottom. I usually make the bottom and back out of one piece cut to size, and then have my local sheet metal shop put the required 90 degree bend in it, but I was in the middle of a snow storm and really wanted to finish this up. So, I cut two pieces and joined them with 1/2″ angle using pop rivets and #6-32 screws as can be seen in **Figure 7**. The cover, front, and rear panel are 1/16″ aluminum and the bottom is 1/8″ aluminum; all #5052 grade material. This grade is easy to bend and still has good machining ability. It can be cut by a table saw with a carbide blade very easily and, in fact, most woodworking tools with carbide cutters can machine this grade. I bend the pieces in a vise with wooden blocks supporting the bend line area, but I can only bend up to 1/16″ thick stock. Beyond that, I go to my sheet metal guy. The cover and front panel are attached to the bottom plate with six 3/4″ long angle brackets (as shown in **Figure 7**) in much the same way as the rear panel was. Next, do the front panel machining and art work, spray paint the cover the color of your choice, and attach the feet. You are now done.



■ **FIGURE 4.**

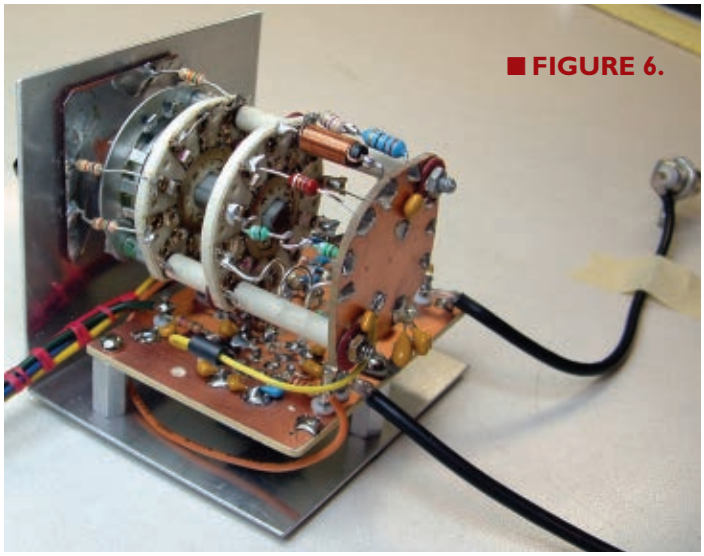


■ **FIGURE 5.**

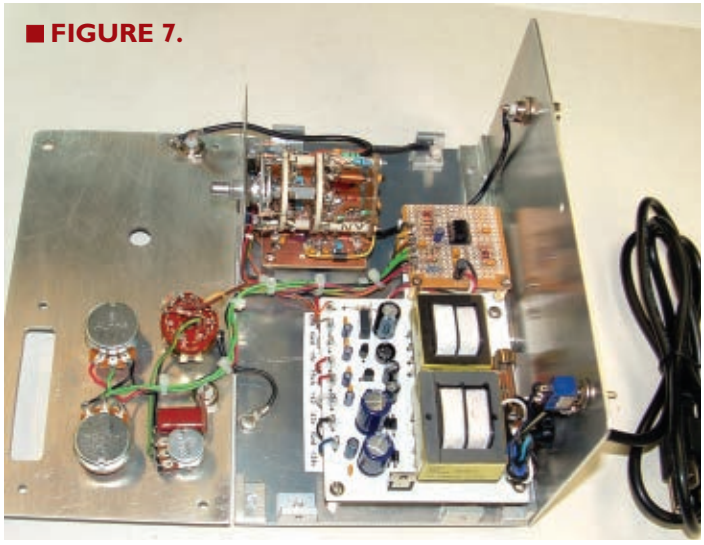
I did drill a 3/8″ hole in the rear panel to install a BNC connector for external frequency counting. As you can see from **Figure 7**, the 120 VAC power-on switch is mounted right above the incoming power cord. I have grown fond of this method the last several years as it saves front panel space, and keeps 120 VAC and its fields concentrated in one spot so I don't have to snake it all over the place to put it on the front panel. (As mentioned earlier, I have more info on this subject available.)

Final Checkout and Operation

At this point, we are ready to do some final testing on the subassemblies and check them out before installing them permanently in the chassis. Starting with the power supply deck, wire up 120 VAC to it and check the outputs for correct polarity and voltage. If all is well here, you can use this to power the RF deck for testing. With the RF deck mounted in its subchassis as shown in **Figure 6**, temporarily



■ FIGURE 6.



■ FIGURE 7.

tack a 15K resistor from the AGC input (low end of R12) to ground just for these tests. For a tuning control, you can temporarily wire a pot and resistor to the Vt input on this deck. Do not install the band switch at this time. Do not connect the 24 VDC supply at this time, either. Do connect the +5 VDC to the deck. You will need all of your coils at this time, plus a 100 µH,10 µH, and 1 µH for these tests. For each of these, tack one coil at a time onto standoff posts A and B. With a scope and frequency meter attached to the emitter of Q3, you should see approximately 360 mV of clean sine wave with each coil used. Don't worry about the exact amplitude as this will be adjusted at a later point in testing.

With any coil installed, vary the tuning range and you should see a bit more than one octave of frequency span for each coil. The exact frequency is not important here, but each coil should give about a 3:1 frequency shift as you increase the coil inductance. Shut off power to the deck and temporarily connect a 51 ohm 1/4W resistor from the RF output jack to ground. Power up and scope this point. There should be about 2,000 mV P-P of clean sine wave here. If all is well, power down and remove the coil.

Prep the switch by soldering a 1" piece of wire to the S2B wiper contact. Also, one item worth adding is a thin 1" square shim of pre-tinned copper with a 3/8" hole in its center, shoved onto the switch mount bolt. This makes it so much easier to install the AGC resistors by giving a convenient ground point. Now, install the switch so that the wiper contact of S2B is positioned right over insulated standoff A. This should be about 1/2" above the post.

Tighten the switch mounting nut. Solder the wiper lead and install the wiring from the RF ground plate on the switch to post B. Add a wire with FB1 from S1a wiper contact to the low end of R12. Now, the individual band coils will be installed.

Starting with the lowest band and as each coil is installed, a frequency check will be made for span and correctness of its labeled bandwidth. The band 8 inductor (see **Parts List**) is just a 1-1/2" piece of bare #22 wire. Start here with a piece a little longer than 2", then trim back as needed while doing the band tests. After you cut it to the length you need, just wind up one or two loose loops if necessary to fit in the space allowed. This will make virtually no change in inductance as opposed to the straight wire.

The coils that you use may not be the same value as mine due to parts tolerances, and there are a lot of tolerances to consider here. The SMV-1404 is a very repeatable component, while the coils can vary by 5% or more. Resistors, pots, and the list goes on. The laws of probability state that half the tolerances will be positive, the other half negative, and they will cancel each other out. Murphy's Law says all tolerances will add in the same direction and render the design useless. In the real world, it's never this bad, but still something to be aware of.

When you purchase coils, it would be a good idea to get a variety close to the **Parts List** values and some at about 5% of the listed values. I actually ordered 50 for this project since it was a new design. The parts are dirt cheap, and it would be a shame to come up short and have to order 80 cents worth of coils for $6 postage. Besides, you can always use the extra in other projects.

Let's get back to installing the tank coils and what you want to achieve here. Strive to get the span needed for the panel labeling (shown with some overshoot) on each end of that band. I ended up with an average of 5% on the ends, but some were as close as 1%. The AGC resistor installation and warmup will shift that span by a very small amount. The actual total span of frequencies should be 0.3 MHz to 150 MHz with no gaps between bands. Mine runs 0.295 MHz to 162 MHz. Having plenty of overshoot is okay, but the most important aspect is that the band switch labels guarantee their stated bandwidth. Can't quite fit everything into my labeling? You can always tweak the Vt voltages to make it fit. Maximum voltages should be no more than

PARTS LIST

ITEM	DESCRIPTION/PART #	SOURCE
All resistors are 1/4W carbon film 5%. All capacitors are in microfarads. Special parts are listed below.		
RF DECK:		
IC1	MC1648 DIP	MC100EL1648 SMD
VD1, VD2	SMV1404-09	
S1	Two-pole, eight-position wafer switch	
Q1	2N5179	
Q2, Q3	2N3904	
MMIC	GALI-55	
FB-1	FB43-226-RC	JW Miller
FB-2	FB43-287-RC	JW Miller
R11	47K, 1/8 watt optional	
R2	390 ohm, 1/8 watt optional	
R10	392 ohm two watt CPF2392R00FKR36	Vishay/Dale
COILS: BOURNS OR FASTRON CONFORMAL COATED		
*See text		
L1	2500 µH	
L2	680 µH	
L3	150 µH	
L4	38 µH	
L5	9 µH	
L6	1.8 µH	
L7	0.33 µH	
L8*	40 nH	
MC1648		
MC100EL1648		Mouser, Digi-Key
VD1, VD2		Contact author
GALI-55		**MINI-CIRCUITS.COM**
Coils		Mouser (usually $0.2-0.4 each)
Resistors		Mouser Electronics
S1		
FB-1, FB-2		Mouser Electronics
CONTROL BOARD & FRONT PANEL:		
IC1	TLO82 or TLO72	
D1, D2, D3	1N916 or equivalent	
P1	10K ALPHA	RV24AF-10-40R1-B10K
P2, P3	10K ALPHA	RV16AF-10-20R1-B10K
S2	ALPHA four-pole three-position wafer	SR2511F-0403-19ROB-E9-N-W
C1	1.0 MFD 200V	(or as low voltage as you feel safe with)
Potentiometers and switch available at **Mouser.com**.		
POWER SUPPLY :		
T1	120V:24V ct @ 0.25A 3FS-424	TAMURA
T2	120V:8V/8V@ 0.3A 3FS-316	TAMURA
REGULATORS:		
7824		Transformers — Mouser or Digi-Key (**www.digikey.com**)
78L12		Regulators — Just about anywhere
79L12		
78L05		MC1648: Datasheets are easily obtained through Google.
7805		GALI-55: Datasheets at **MINI-CIRCUITS.COM**.
		SMV1404-09: I stock these.

+0.7V on the low end by virtue of R9 and R10 on the control board, and -7.0 volts on the high end of the tuning pots by changing R3. Still can't get everything to fit? Then do what I did: change the artwork on the front panel labels.

When all is set and done with this part of the testing and you have a minimum warm-up period (10 min), you can now adjust the AGC voltage for each band. Start with the lowest band first. Hopefully, you own a resistor substitution box to connect to the S1A wiper and ground. Load the output with a 51 ohm resistor and connect a scope at that point. As you run through each band, adjust the resistance for +10 dBm (2,000 mV P-P) output and make sure you tune through the band to select for the best overall flatness. Make note of the R value for each band as you proceed.

You will probably find the same value of resistance will work for several bands, minimizing the resistors ultimately needed. One word of caution here: I use a Tektronix scope with a 350 MHz -3 dB bandwidth, but it is only perfectly flat out to 100 MHz. Beyond that, it rolls off in typical Gaussian fashion. However, I have had it calibrated for sine waves all the way to 500 MHz in a 50 ohm environment. Now, I have a look-up table so that regardless of what the scope displays, the table tells me what the correction factor needs to be. Most scopes will do a fair job up to 40 MHz or 50 MHz, but if you do not trust your scope beyond that point, then use the AGC values shown in the print for band 8. At this point, you can complete the unit and close it up.

Closing Notes

The output of this generator has an exceptional amplitude response of ± 0.1 dB on bands 1 through 7, and

The frequency counter was omitted from the images for clarity and is an article in itself. *N&V* have given me the green light on this and I am in the mid stages of design. So, hopefully, that article will follow on the heels of this one. Stay tuned!

± 0.5 dB on band 8. This is due to the built-in AGC circuits of the MC1648. I did not do an FFT on the output, but after looking at scope sine wave presentations for over 40 years I have developed a pretty good eye for distortion, and would judge spurious and harmonics to be a good 30 dB below the output level. That is a clean sine wave and very respectable for this type of generator. LC oscillators do not have the long term stability as their crystal referenced "big brothers" do, and usually will drift 500 ppm or more over a given time. Although this one is no exception to that rule, it out-performs those figures by quite a bit.

After a one hour warmup, I performed many tests for short-term stability of 15 minute periods. I did this for each band at the low, mid, and high ends of their ranges — 24 tests in all. The best case was 2 ppm drift in that time and the worst case was 98 ppm. The rest varied from 20 to 80 ppm, with 50 ppm being a good overall average. So, I could conservatively spec the overall short-term stability at 100 ppm which is quite good for an LC oscillator. I was also pleasantly surprised that I could easily inject a signal into the input of a narrow band land mobile receiver at 155 MHz and hold that input for quite a while — although it did show a sensitivity to load changes in those frequencies.

The external modulation input was set arbitrarily at 800 mV P-P for all inputs. In the AM mode, 50% modulation can be obtained before soft clipping and then hard clamping occur. This function has a good linearity figure of 3% and about 15 mV P-P for each percent of modulation sensitivity. The clamp circuit prevents the MC1648 from damage due to accidental over-voltage of input here. Without the clamp, it has the same linearity up to 90% mod. Unless you are feeling lucky, do not bypass this feature. The standard test signal for AM is 30%, so this is achieved and then some.

The FM mod input is attenuated quite a bit in the summing amplifier and is not so prone to over-voltage. At a full 800 mV P-P, it will produce a deviation of approximately 0.5% of the carrier frequency. A calibrated FM deviation is very difficult to achieve and would require twice the circuitry as the entire generator with specially machined switches, so it was not even considered for this design. However, if you have a few "pet" frequencies that you would like a known deviation for, there is one method of achieving this. Set the generator to the carrier frequency desired and carefully inject a DC voltage of zero at the junction of C7 and R7 on the control board, with the mod control set for FM operation. Note the frequency and slowly increase the DC voltage until the carrier frequency increases by the amount of deviation desired. An AC P-P voltage that is the same as that DC voltage will now give the exact amount of deviation you want. If you do this often, a rear panel jack connected to that point would make things easier. Just keep in mind that the DC eventually winds up on the Vt line to the varactor because there is no blocking capacitor in that path.

There are a couple of changes that I made that are not shown in the images. On the RF board, I extended the leads of R10 to 1/2" on both ends so as to mount it higher off the board, and bent it slightly away from the board. This resistor dissipates one watt, and was dissipating a lot of that heat into the copper foil. This is the one exception to the "short leads" rule. The added inductance of the leads will only affect band 8 by increasing the MMIC's load impedance. The effect is so minimal that it can be ignored. It still couples some heating to the board and — along with the upside down mounting of the MC1648 adding yet more board heating — they will raise the board temperature about 13 degrees F above the work area's ambient.

Of course, some of that heat is generated by transformers, regulators, and such. This is why it takes about a full hour warm-up to stabilize. However, after a couple of minutes, the generator is ready for use. Just let it warm up for an hour before doing critical work such as IF alignment, etc. The other change was adding a 1" square of thin aluminum to the 7824 regulator tab in the power supply as it tended to run too hot without this.

I did not design an RF attenuator in this unit to keep its footprint as small as possible. Years ago, I bought a really low priced HP attenuator on eBay. It will attenuate 0-130 dB in 1 dB steps, and with HP quality. I find that I use this attenuator even with equipment that has one built in due to its wide bandwidth and precision.

In my sweep generator article mentioned previously, I show construction of an attenuator that won't bust your wallet. It has decent performance to upwards of 200 MHz and about 5% accuracy. This is a four step 0-40 dB in 3 dB steps. This could be expanded to 0-100 dB in 1 dB steps by using 27 5% 1/4W resistors and nine DPDT mini switches, plus some double-sided circuit board for a housing at a cost of maybe $30. The switches could be mounted vertically in a single column on the left side of the panel.

Either way, you would have to add another 1-1/2" to the panel width to accommodate these. (I could include this in the email packet.) If you are desperate for an attenuator, the "cheap and dirty" version shown in **Figure 2** will suffice as far as more power/less power goes. Also, there will be an insertion loss of 3 dB (for the MMIC protection) and it will not be calibrated. For five dollars in parts, it will get you by.

As to what I might change in the future: replacing the fine-tune pot R2 with a three-turn pot for even finer adjustment; and adding an internal tone oscillator with 800 mV P-P output. Then, I'd connect this to the front panel jack via a miniature SPDT toggle switch.

I am always changing designs for the better as new ideas and components become available. I do have an outboard clock generator design for this generator included in the email packet. It runs at exactly half the frequency of the RF output feeding it, and has a perfect square wave with rise and fall times in the low nanoseconds. When doing this project, take your time and double-check connections as you proceed. Most of all, have fun! **NV**

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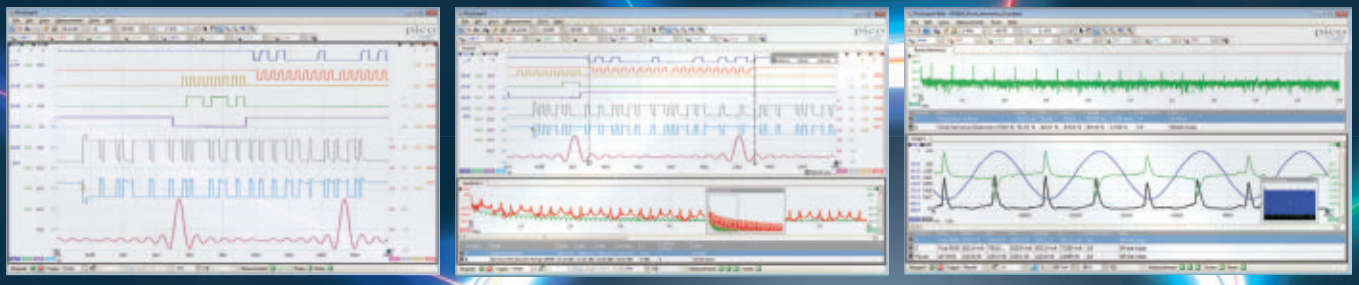

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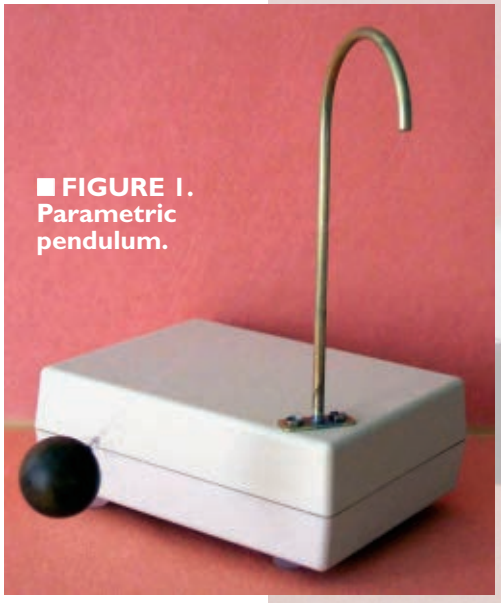


■ **FIGURE 1. Parametric pendulum.**

On a warm summer day, there were a few kids playing on a swing set in the park. Farthest from me was a boy swinging with another boy pushing him from behind. Closer to me was a girl swinging all by herself. Her swing went as high as the boy's and the arc of her swing continued without decaying. It was easy to understand the motion of the boy being pushed as a reaction to an equal and opposite force, but the girl had nothing to push against. What magic was she using?

The swing can be thought of as a mechanical resonate oscillator that alternately stores energy in the form of both kinetic and potential energy. The kinetic energy is maximum at the bottom of the swing where the velocity is maximum. The potential energy is maximum at the extremes of the swing where it is at the highest points and the kinetic energy is zero. The boy pushing the swing adds kinetic energy to maintain the motion, while the girl adjusts her center of mass alternately up and down to add potential energy to maintain her motion.

The concept applies to both mechanical and electronic oscillators. An electronic oscillator alternately stores kinetic energy in the inductor as the magnetic field, and potential energy in the capacitor as the electric field.

This explanation is very much simplified but is sufficient to describe the concept of a parametric amplifier. Additional information can always be found on an Internet search.

One distinguishing characteristic of a simple parametric amplifier is that the energy is pumped at twice the resonate frequency, as opposed to a driven oscillator where the drive frequency is equal to the resonate frequency. The phase of the pump frequency and the oscillation is also very critical, so that the mass of the pendulum is lowered at the extremes of the swing and raised at the center so the motion is in the form of a figure eight.

The term "parametric amplifier" comes from the time varying coefficients of the mathematical equations that describe the motion. A generalized treatment was first given by Lord Rayleigh in the late 1800s, and since then many papers have been written to describe the complexity of the phenomenon and its many variations.

In the early days of radar development, it was necessary to design very low noise microwave receivers at a time when very few devices could even work at microwave frequencies. Parametric amplifiers provided a very attractive solution to this problem since they could be built with a simple varactor diode (voltage controlled capacitor) to pump a resonate cavity and provide gain. Both in theory and in practice, the parametric amplifiers could also provide very low noise.

Theoretically, a parametric amplifier can produce zero noise since the modulating unit is an energy storage device, or completely reactive in which the voltage and currents are 90 degrees out of phase. This is opposed to a conventional amplifier in which the modulating device is resistive and inherently adds noise because the voltages and current are in phase. In reality, the parametric amplifier adds some noise because the phasing of the pump frequency and the desired resonate frequencies are not exactly known. In addition, the energy storage devices are not perfect and produce losses.

We can build a mechanical model of a parametric amplifier in the form of a simple pendulum that continues to swing like perpetual motion as illustrated in **Figure 1**. The pendulum could be referred to as a degenerative parametric amplifier because the pump frequency is twice the resonate frequency of the pendulum, and the pump phase is critical. Fortunately, the phase of the pendulum is free when excited and will drift into phase lock with the pump oscillator, and build up the swing.

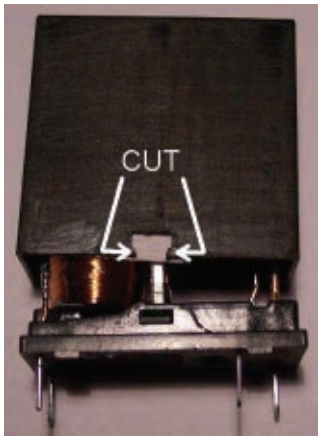
There are also non-degenerative parametric amplifiers that employ a third frequency to eliminate the rigid restraints on the phase relationship.

The Actuator Relay

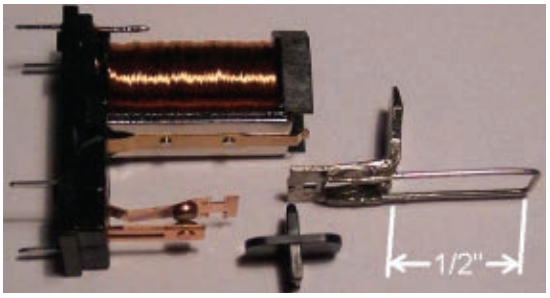
The model employs a modified relay to pull the string to modulate the potential energy of the pendulum. A Panasonic JQ1A-9V relay was purchased from Mouser Electronics and is one of the few that is not hermetically sealed. It has a nine volt coil and runs about 23 milliamps when energized. Other relays can be used, especially the

PARTS LIST

ITEM/DESCRIPTION #	COST
Mechanical Parts:	
1/8" OD x 0.014" wall x about 8" long brass tubing	$1.80/ft
3/32" OD x 0.014" wall x about 8" long brass tubing	$1.80/ft
0.040" OD x 0.010" wall x about 8" long Teflon tubing	$3.00/2 ft
0.010" OD x about 14" long Spiderwire EZ fluoro fishing line	$7.99/200 yds
Hobby Lobby 211201, 3/4" OD wood ball	$1.99/nine balls
Electronic Parts:	
K1 Panasonic JQ1A-9V relay	$3.52
U1 ICM7555 CMOS DIP timer IC	$0.88
R1 2.2 megohm, 1/4 watt resistor	$0.03
R2 500K ohm 25-turn trimpot	$3.50
C1, C2 0.1 µF, 50V, ceramic	$0.10
C3 10 µF, 25V, electrolytic	$0.25
D1 1N4148 diode	$0.10
B1 9V battery	$1.70
9V battery connector	$0.45
LMB Heeger 502 plastic case	$9.36
Miscellaneous:	
Perfboard (or RadioShack PCB #276-159)	$2.60
Eight-pin DIP socket	$0.15
Scrap 1" x 1/2" x 1/16" thick fiberglass or plastic base	
Double-sided foam adhesive mounting tape about 1" x 1/2" (try Magic Mount 3701)	$8.00/16 strips
Five minute epoxy adhesive	$6.00
Crazy Glue	$3.00
Several #4 x 1/4" self-tapping mounting screws	$0.50



■ **FIGURE 2A. Relay case removal.**



■ **FIGURE 2B. Actuator conversion.**

older relays that are larger with snap-on covers. Higher or lower voltage versions can also be employed with a DC power supply such as a wall wart. If you use a wall wart, make sure that the unloaded voltage does not exceed the 18 voltage rating of the CMOS 7555 pump oscillator.

Figure 2A illustrates the cover locks located on each side of the relay. Two cuts were made on each side of the relay with a sharp Xacto™ knife so the cover could be carefully removed.

Figure 2B illustrates the internal parts of the relay. The black plastic switch actuator can be carefully removed with a pair of tweezers or small long nose pliers. Then, the relay armature can be removed by pulling it forward from under the golden colored spring clip. The armature is modified by adding a length of wire to increase its motion and provide a place to tie the pendulum string.

A stiff 0.020″ diameter steel wire was used, but almost any wire such as 22 AWG copper wire will work. The wire can be attached with five minute epoxy adhesive or soldered in place so that the wire loop will add 1/2″ to the armature as illustrated in the photo. This will allow the pendulum mass to be pulled about 1/16″.

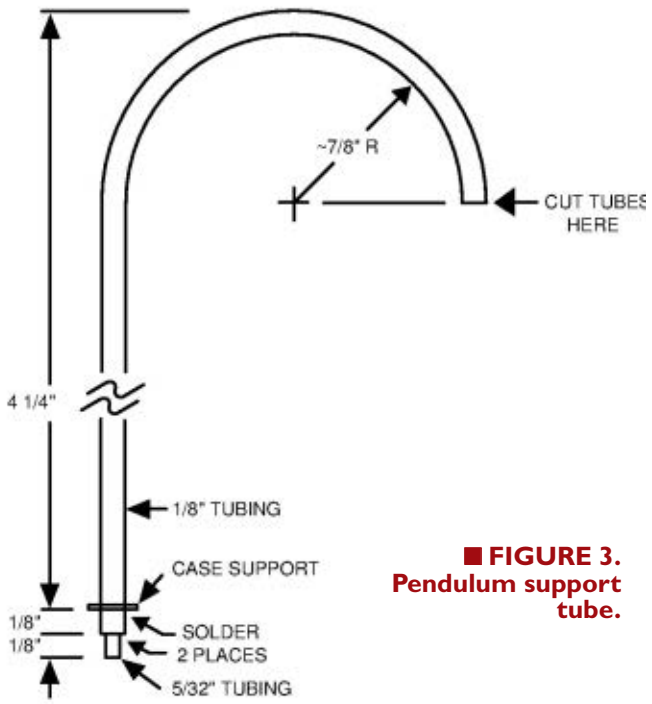
A 1/2″ wide by 1″ long piece of scrape PCB (printed circuit board) fiberglass was glued to the relay as a base with five minute epoxy (illustrated in **Figure 5**). Alternately, scrap pieces of plastic about 1/16″ thick can be used.

Pendulum Support Arm

The pendulum support arm is made from brass tubing as shown in **Figure 3**. Similar tubing can be bought from a hardware or online store. It consists of a 3/32″ OD x 0.014″ wall brass tube inserted inside a 1/8″ OD x 0.014″ wall brass tube for rigidity. The smaller tubing extends out about 1/8″ from the larger tubing at the bottom, and they are secured together by soldering the outer ends together. Other tubing such as stainless steel can be used.

The support should be rigid because one model employing a single 1/16″ OD x 0.014″ wall brass tube failed to work because the support vibrated and damped any oscillation. This could be demonstrated by holding the end of the support tube rigidly with a third-hand alligator clip to observe the pendulum oscillation.

The tubing was bent by hand around a 1-3/4″ diameter glass spice bottle to form a smooth 180° bend. Any excess tubing can be cut off with a Dremel cutoff wheel. A 1/2″ wide flat strip of brass with a 1/8″ hole was soldered 1/4″ up from the bottom as a support to the case. Alternately, a metal washer can be soldered at this point to act as the support.

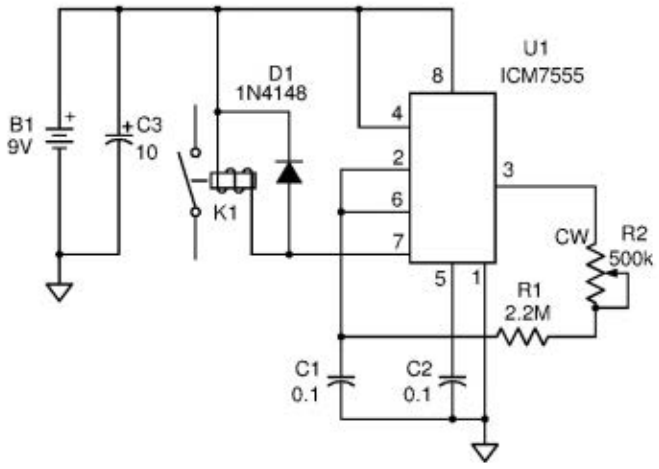


■ **FIGURE 3. Pendulum support tube.**

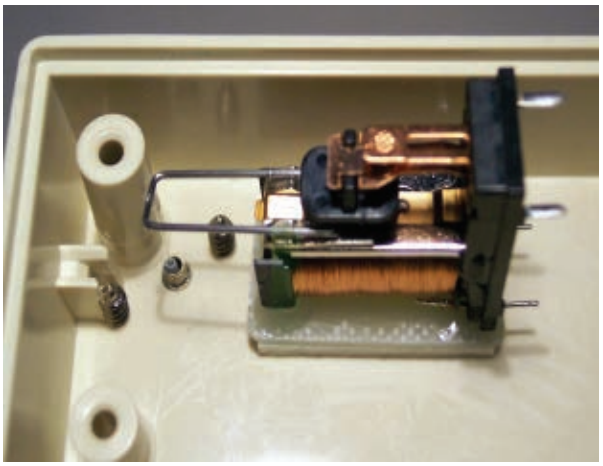
■ **FIGURE 4. Wire wrap around Teflon tubing.**

The inside of the 3/32″ brass tube was lined by inserting a 0.040″ OD x 0.010″ wall Teflon™ tubing inside to reduce friction and wear. Similar Teflon tubing can be purchased from online stores. Alternately, the solid copper wire can be pulled out from a piece of Teflon insulated hook-up wire for the spaghetti.

At the upper end of the Teflon, a piece of 30 AWG copper wire was



■ **FIGURE 6. Pump oscillator schematic.**



■ **FIGURE 5. Actuator mounted in case.**

wrapped tightly around the Teflon tubing with four turns as illustrated in **Figure 4**. Even though the Teflon is slippery, the tight wire wrap mechanically holds the Teflon tubing securely. Several drops of Crazy Glue™ were placed on the wire wrap, and the Teflon tubing was pushed back inside the brass support tube so the glue would anchor the wire, and thereby the tubing.

After the glue dried, both ends of the Teflon tubing were cut off with a razor blade. This tends to flatten the end of the tubing, so its circular shape should be restored with a small wire or tapered tool.

The Case

A LMB Heeger case #502 was purchased from Mouser Electronics; it has a compartment for a nine volt battery. A 1/8″ diameter hole was drilled in the top of the case at one corner, being careful to miss any plastic obstruction inside the case top. The brass support tube is fitted into this hole and the support can be attached with five minute epoxy adhesive, or alternately drilled and fastened with self-tapping screws so the support arm extends out over one corner of the case.

Four rubber feet are attached to the under side of the case, so it will be stable and less likely to rattle around.

Pendulum String

The string is 0.010″ diameter Spiderwire EZfluoro fish line purchased from Walmart or a similar sporting goods store. This is sold as 100% fluorocarbon, but is a related material known as PVDF (polyvinylidene fluoride or polyvinylidene difluoride) with a low melting point of about 177° C.

A knot following the instructions on the package was tied to the additional armature wire of the relay and then fed into the Teflon tubing from the bottom. The knot can be more securely fixed with a drop of Crazy Glue. The glue doesn't stick to the Spiderwire but will mechanically lock the knot and help prevent it from unwrapping.

Expose one adhesive face of a piece of double-sided foam mounting tape and attach it to the PCB fiberglass bottom of the relay. Expose the second side of the foam tape and position the relay firmly in place so the fish line is directly over the Teflon tubing as shown in **Figure 5**.

Pendulum Ball

The pendulum ball is a 3/4″ diameter stained wooden ball that was purchased from Hobby Lobby (#211201). A 1/16″ diameter hole was drilled about 3/32″ deep into the ball and a doubled-over 22 AWG copper wire was inserted as a loop and secured with five minute epoxy.

With the case on a table, secure the free end of the fishing line to this hook with another knot so the ball will hang free about 1/4″ above the table. This knot can also be mechanically locked with a drop of super glue.

The length of the model's string from the top end of the brass support tube to the top of the ball measured 4″. Add to this the radius of the ball and it gives the total pendulum length to the center of mass. The frequency of a simple pendulum is given as:

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$$

where g is equal to 32.2 feet/second^2 (the acceleration of gravity). Using these values, the frequency of the model is about 1.5 Hz.

The Pump Oscillator

The pump oscillator schematic in **Figure 6** employs the CMOS ICM7555 timer chip. The circuit is configured to provide a square wave frequency given as:

$$f = \frac{0.722}{RC}$$

R should be on the order of 2.4 megohms for a pump frequency of about 3 Hz, and *C* fixed at 0.1 µFd. *R* is made up of a standard 2.2 megohm resistor in series with a 500K ohm potentiometer to trim the frequency. The circuit is simple, so the pump oscillator was constructed on perfboard with point-to-point wiring and mounted in the lower half of the case where the battery compartment is located. Leave long leads to connect to the relay actuator to allow access to the oscillator trim pot for adjustment of the correct frequency.

Frequency Adjustment

The bandwidth, Δf, at the half power point or sharpness of resonance is defined as:

$$Q = \frac{f}{\Delta f}$$

The *Q* factor can be measured by releasing the pendulum at a given angle and recording the time, τ, for the angle to decay to about one-third its initial value. The *Q* factor is then calculated from the relationship:

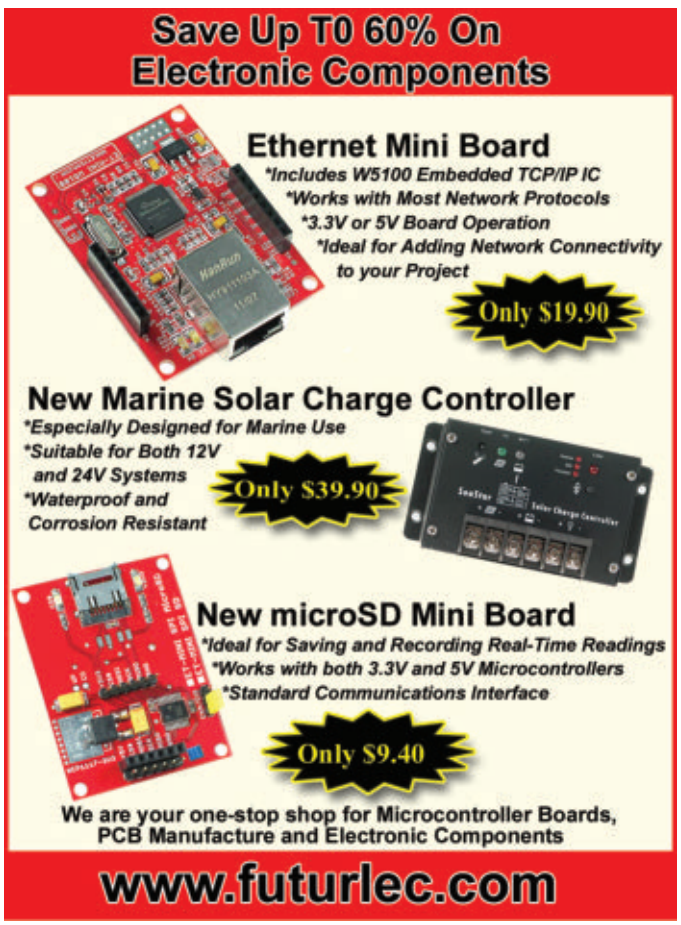
$$Q = \pi f \tau$$

The factor *Q* of the pendulum is on the order of 150, so the pump oscillator frequency is quite critical and must be set at exactly twice the pendulum frequency. The pendulum period can be easily obtained with a stopwatch by measuring, say, 10 full cycles and dividing the elapsed time by 10 to obtain one period. Alternately, an optical tachometer could be used to measure the period of the pendulum, and a frequency counter to set the pump oscillator frequency.

I have used a small silicon photovoltaic cell taped on the table directly below the pendulum and connected to a sensitive oscilloscope. The photocell is illuminated from above the pendulum with a bright flashlight, so a voltage pulse from the pendulum shadow is cast every time the pendulum swings over the photocell. There will be two shadow pulses generated for every swing of the pendulum because the pendulum has two zero crossings per cycle of a sine wave. The pump oscillator trimpot R2 is then set, so the complete time of one cycle of the pump oscillator is equal to the time between any two shadow times of the pendulum.

This completes the construction of the parametric amplifier model. It's called an amplifier rather than an oscillator because the pendulum must first be excited with a signal (such as a large push) to start it swinging. A large perturbation will allow the pendulum to continue to oscillate long enough for the phase to slip into sync and execute a swing of about ±2″.

Now *you* know how it works, but to your friends it will be magic. **NV**



 Continued from page 23

HIGH POWER WI-FI PCI-E ADAPTER

Amped Wireless has announced the availability of its PCI20E high power AC1200 Wi-Fi PCI-E adapter. The PCI20E is a high performance Wi-Fi adapter designed to add long-range Wi-Fi connectivity and ultra-fast data transfer speeds to Windows desktop computers.

The PCI20E uses the latest 802.11ac Wi-Fi technology to provide maximum wireless speeds for demanding applications such as streaming HD video and online gaming. It features two high-gain dual band antennas and four total amplifiers for up to 500 mW of wireless output power to provide maximum range and performance. In contrast, standard Wi-Fi adapters provide up to 100 mW of power and are not capable of providing extended range. The PCI20E provides up to three times the range of standard adapters and is backwards compatible with 802.11a/b/g/n networks. It connects using PCI-E for easy installation into any computer case.

All Amped Wireless products include the Wi-Fi Analytics Tool App — free for Android and Windows devices to help users analyze and optimize their networks. The app allows users to fine-tune their network to get the maximum speed and coverage. The PCI20E has a retail price of $79.99.

For more information, contact:
Amped Wireless
Web: **www.ampedwireless.com**

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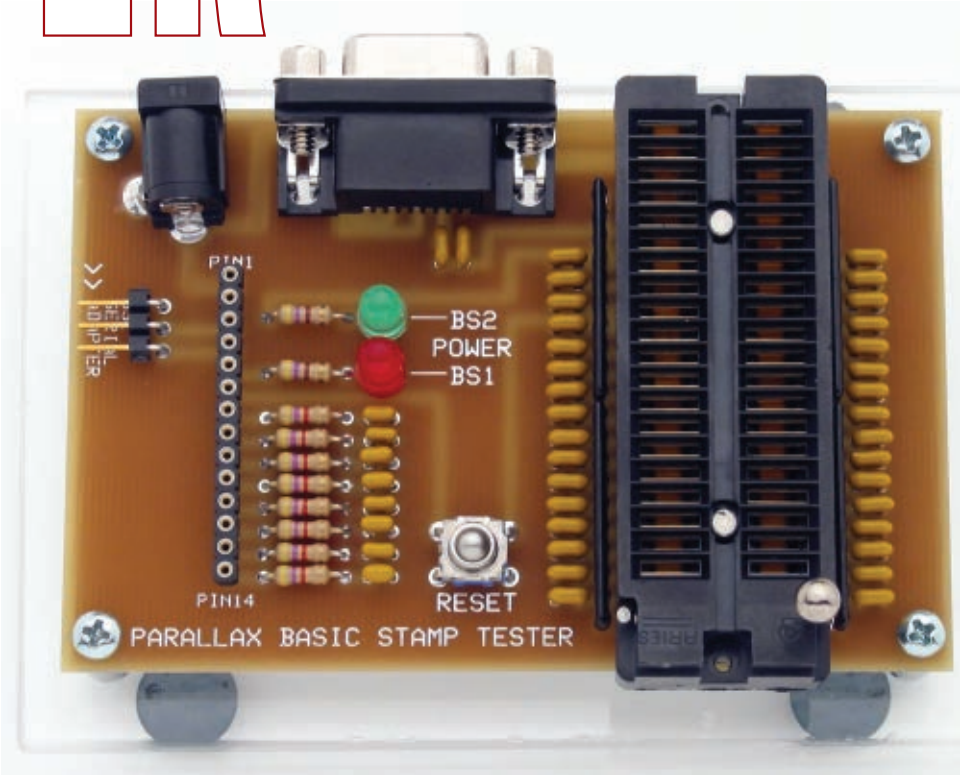
BASIC STAMP MODULE TESTER

By Chris Savage

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com /index.php?/magazine/article/ june2014_Savage.**



This easy-to-build-and-use tester will allow you to test any BASIC Stamp modules for bad I/O pins, RAM, and other issues that may cause problems in your projects. This tester only works on Stamps that can still communicate with a PC and cannot test modules that are completely dead (bricked).

A Little History

BASIC Stamps are one of the most well-known microcontrollers out there. That popularity is well deserved, and includes vast amounts of free documentation and example code, as well as free technical support. Parallax takes great pride in manufacturing these microcontrollers here in the USA, and every Stamp made is fully tested before being sold. This procedure is done one Stamp at a time, usually in lots of 50, 100, or more.

Over time, Parallax has developed and improved the testing of their modules. Originally, there were separate programs and test boards for each Stamp model. My goal as a tech guy at Parallax was to have one board and source code to handle everything.

To that end, I worked with Senior Application Engineer Jeff Martin to not only simplify the test procedure for manufacturing, but make it better and be able to detect more possible types of problems. While the code was being improved, I created a test board that could handle any Stamp module. This includes the BS1 and all 24- and 40-pin Stamp 2 models.

Parallax has allowed me to release the code and plans for this board, as well as another tester I built for exceptions — the exceptions being boards like the HomeWork board, Sumo board, and Toddler board where the Stamp is surface-mounted and cannot be removed to plug into this test board. First, I'll cover the test board, then the card tester.

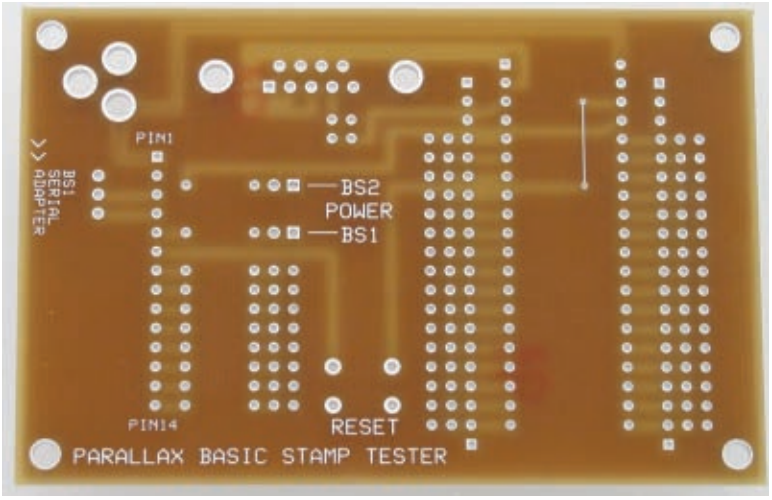
ExpressPCB is Fast and Easy

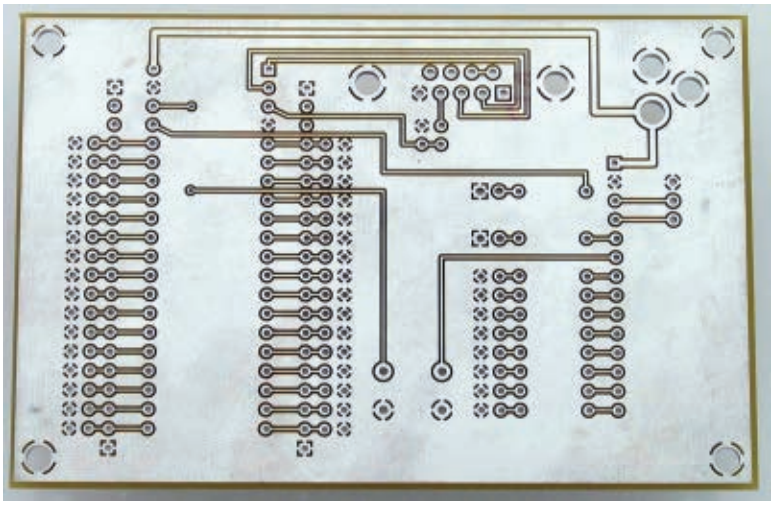
I needed the board in a hurry and already had a reference schematic, so I used ExpressPCB to quickly create the printed circuit board (PCB) you see in **Figures 1A** and **1B**. Using the mini-board service, we got three of these for under $60 in three days. The ExpressPCB file can be downloaded from the article link or from my project page (see **Resources**). As you can see from the solder side of the board, all ground connections are part of the ground plane.

Assembly Time

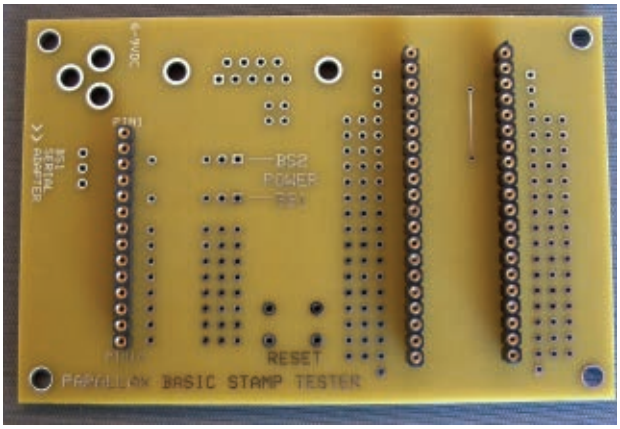
For me, populating a PCB begins with the smaller components. I do this to make it easy to solder sockets and resistors, while being able to lay the board down flat on a surface. Once the smaller components are in, I start working my way up. See the **Parts List** for what was used.

■ **FIGURE 1A. PCB front.**

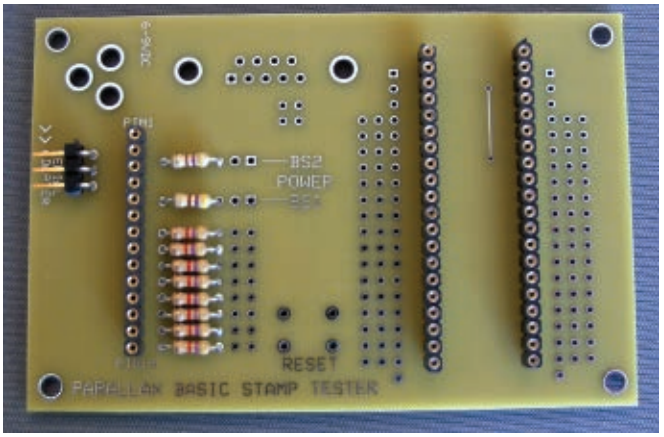




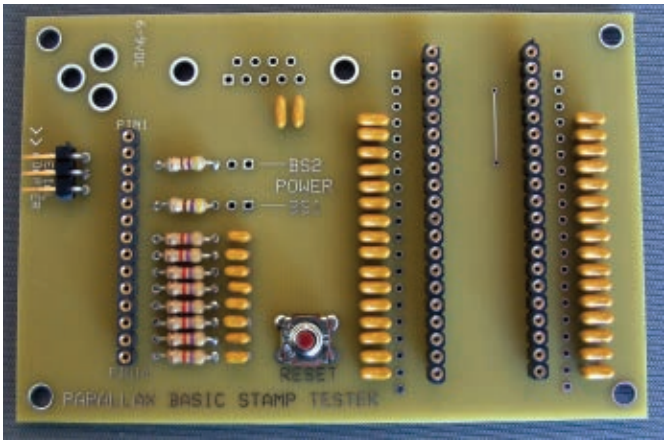
■ **FIGURE 1B. PCB back.**



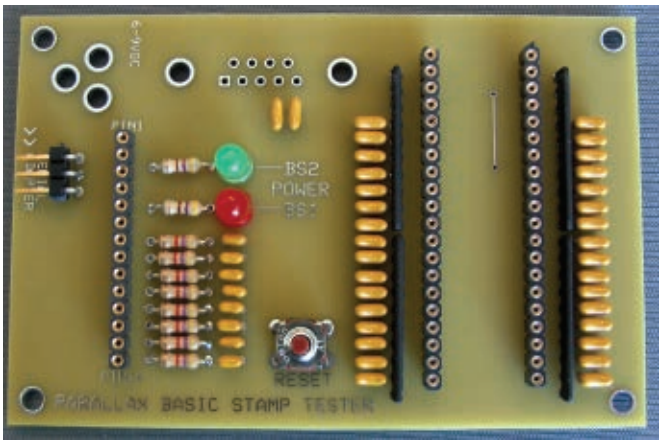
■ **FIGURE 2. One 14-pin and two 20-pin machined sockets.** The 14-pin socket mounts on the left side of the board. The two 20-pin sockets on the right need to line up with the ZIF socket in the end, so I plugged it in until I got these fully soldered. I then removed the ZIF socket for the rest of the assembly.



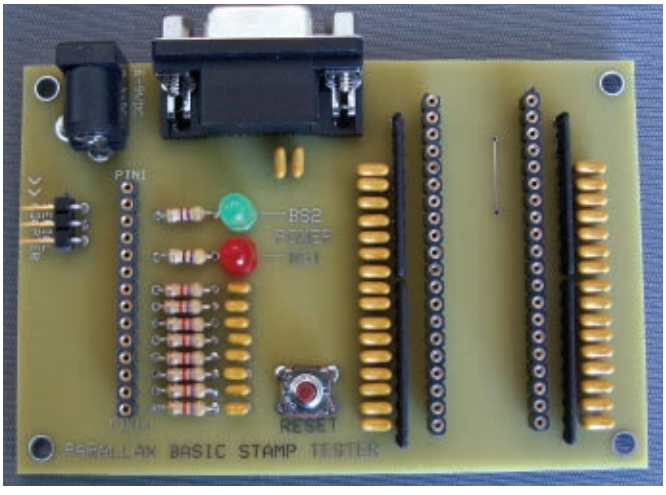
■ **FIGURE 3. One three-pin RA SIP header, eight 4.7K resistors, and two 470 ohm resistors.** The three-pin RA SIP header mounts on the far left. This is where the BS1 serial adapter connects. The 4.7K resistors run from the bottom-right of the BS1 socket about half way up. These are connected to the BS1 I/O pins. The 470 ohm resistors mount above the 4.7K resistors and control current to the LEDs. Note: These (values) may be changed as needed for the color LEDs you use.



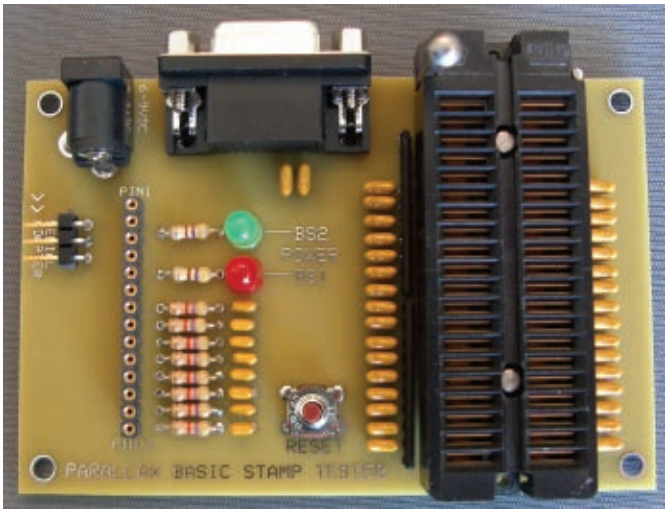
■ **FIGURE 4. Eight .01 µF capacitors, 34 .1 µF capacitors, and one tact switch.** The eight .01 µF capacitors (marked 103) install just to the right of each 4.7K resistor. Thirty-two of the .1 µF capacitors (marked 104) install down either side of where the 40-pin ZIF socket will install. The other two install just below where the DB-9 mounts. Note the orientation of these two as it differs from the others (vertical rather than horizontal). The RESET switch mounts bottom-center of the board and should only fit one way.



■ **FIGURE 5. Four 10K SIP resistor packs and two LEDs (any color).** The 10K SIP resistor packs should have a dot or line to signify pin 1. This is very important as these are bussed and have a common ground pin which must be at the square pad on each of the four areas they're on. The LEDs can also be mounted. Color does not matter and you can always use two of the same color if you want.



■ **FIGURE 6. One DC power jack and one DB-9 RA serial connector.** Mounting holes for the DC power jack are slightly large on the units I have. Be advised that you should exercise caution installing this unit because you'll need a lot of solder, but you don't want to melt the connector or damage the PCB from excessive heat. The DB-9 should snap right in. I only put a little bit of solder around the mounting tabs since they practically lock in place anyway. The solder there is more to keep the tabs from unlocking. Those holes don't need to be filled.

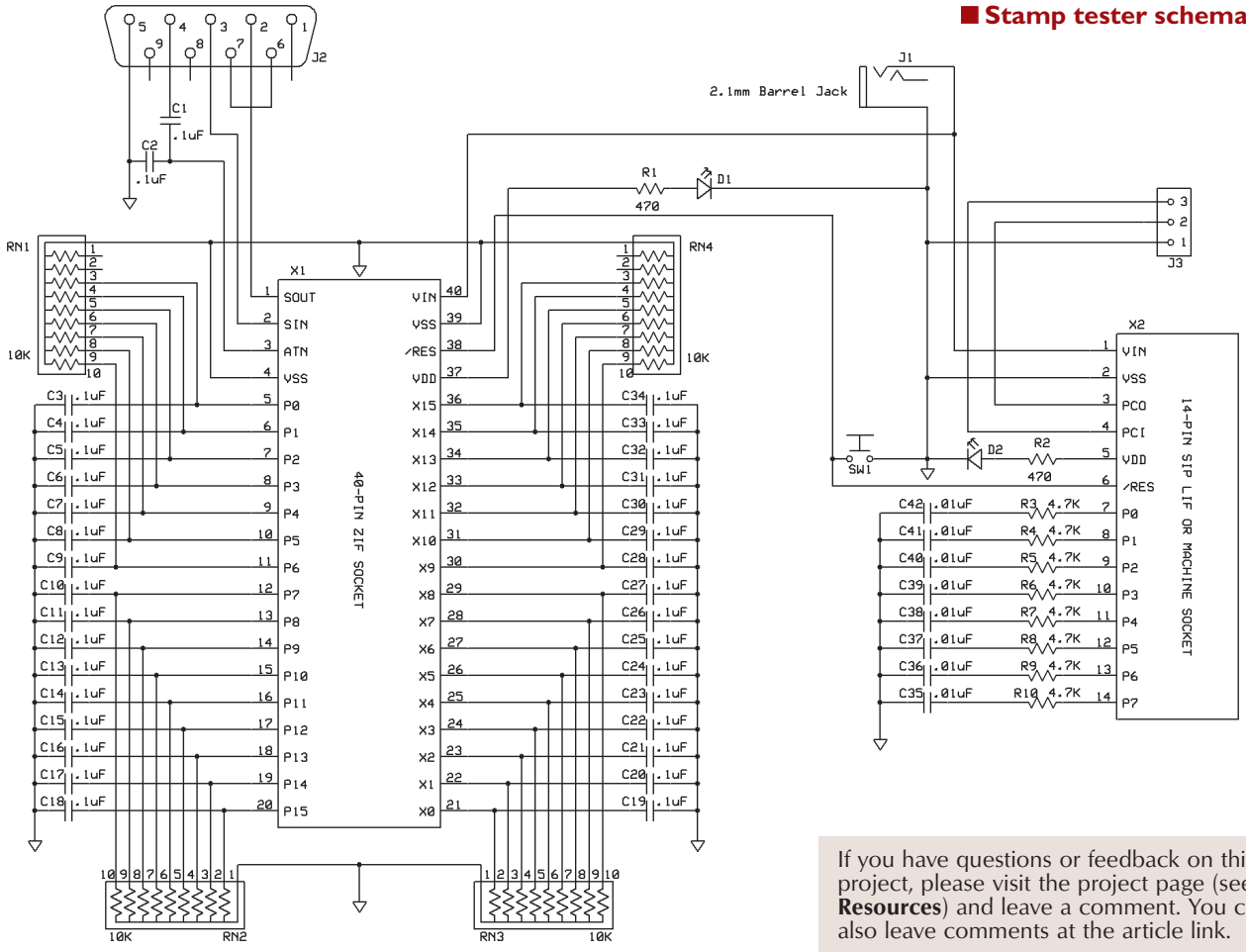


■ **FIGURE 7. One ZIF socket.** Finally, snap your ZIF socket into place and you're ready to start testing BASIC Stamps. Source code is located at the article link.

Exceptions to the Rule

As previously mentioned, there are a few Stamp-based boards we cannot put into the tester because they are surface-mount (HomeWork, Sumo, and Toddler). So, for those, I designed a card-type solution that could plug into the 16-pin SIP socket available on all three. In fact, the card could be used on the Board of Education (BOE), Professional Development Board, or any other board that has a 16-pin socket with access to the I/O pins on the Stamp. (This allows you to test it on a development board if you should choose to.)

■ **Stamp tester schematic.**



If you have questions or feedback on this project, please visit the project page (see **Resources**) and leave a comment. You can also leave comments at the article link.

PARTS LIST

Designation	Qty.	Part #	Source	Description
PCB	1	N/A	ExpressPCB	Tester printed circuit board
X1	1	A307-ND	Digi-Key	40-pin ZIF socket
X2	1	A24817-ND	Digi-Key	14-pin SIP machine or LIF socket
J1	1	SC1313-ND	Digi-Key	DC barrel jack, 2.1 mm, RA
J2	1	A2100	Digi-Key	DB-9, RA
J3	1	451-04002	Parallax	Three-pin header, RA (cut from 40-pin)
SW1	1	400-00002	Parallax	Tact switch
D1-D2	2			LED (color of choice)
RN1-RN4	4	4610X-1-103LF-ND	Digi-Key	10K SIP resistor, bussed
R1, R2	2	150-04710	Parallax	470 ohm 1/4W 5%
R3-R10	8	150-04720	Parallax	4.7K 1/4W 5%
C1-C34	34	200-01040	Parallax	.1 µF
C35-C42	8	200-01031	Parallax	.01 µF

CARD TESTER PARTS LIST

Designation	Qty.	Part #	Source	Description
PCB	1	N/A	ExpressPCB	BASIC Stamp Tester CS PCB
R1-R16	16	150-01030	Parallax Inc.	10K, 1/4W, 5%
C1-C16	16	200-01040	Parallax Inc.	.1uF, 100V, 10%

Resources

Project Page
www.savagecircuits.com/stamptester

Parallax Inc.
www.parallax.com

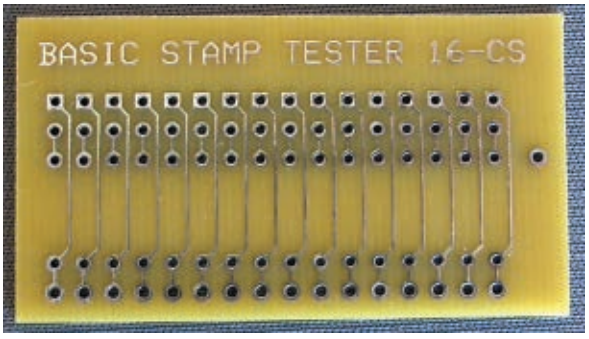
Digi-Key
www.digikey.com

Savage///Circuits YouTube Channel
www.youtube.com/savagecircuits

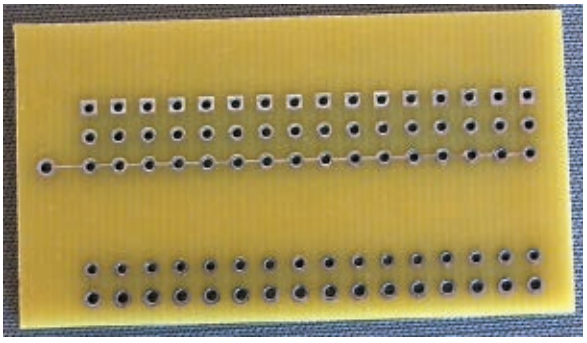
Assembly Time ... Again!

This next board is much smaller, requiring only three different parts. **Figures 8A** and **8B** show the front and back of the PCB. The layout is intentionally simplistic.

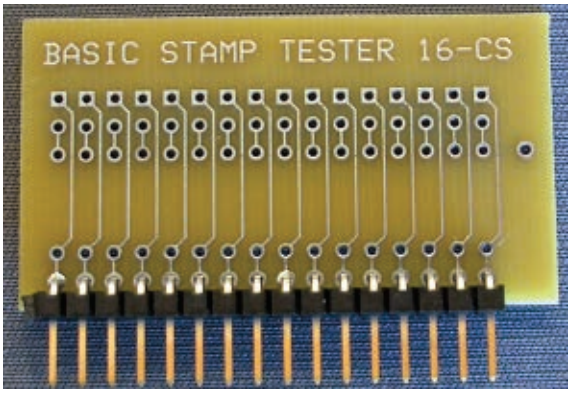
Again, ExpressPCB came to the rescue with fast boards. Of course, as small as this design is, I managed to get 12 modules out of one order of the mini-boards by panelizing the design.



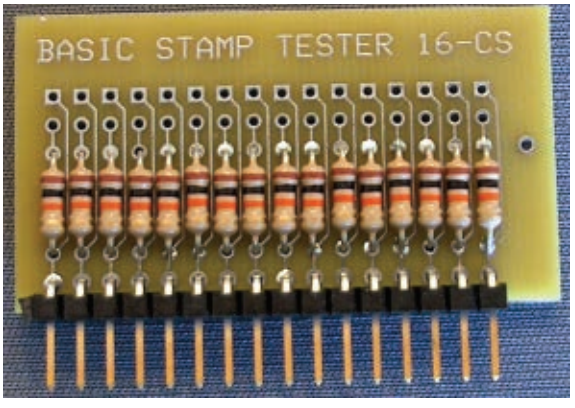
■ **FIGURE 8A. PCB front.**



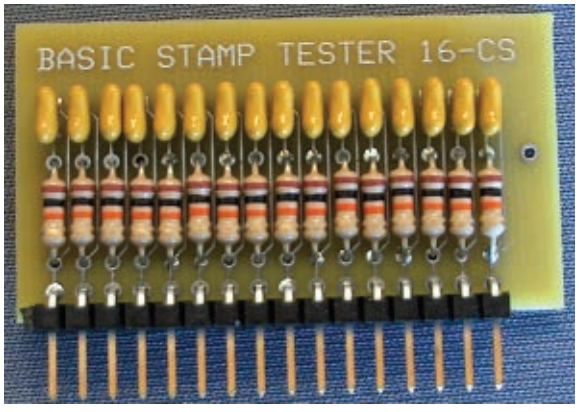
■ **FIGURE 8B. PCB back.**



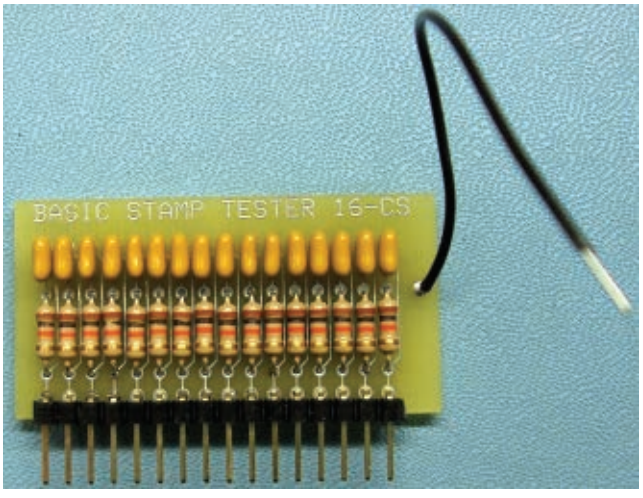
■ **FIGURE 9.** The 16-pin RA SIP header. Just mount this header along the bottom edge.



■ **FIGURE 10.** Sixteen 10K resistors. These go in the lower set of holes.



■ **FIGURE 11. Sixteen .1 µF capacitors.** These go in the upper set of holes. Now, your tester is complete! (Oh, so you're wondering about the extra hole?)



■ **FIGURE 12.** The extra hole was for an optional grounding wire. Originally, the design required a grounded bus. However, the state of all the other lines during the tests acts as an effective ground, making the wire unnecessary.

Testing BASIC Stamp Modules

The first thing to realize is that these testers cannot detect all issues or failures. The most obvious case is that the Stamp cannot be detected by its editor or some other communication error. The tester is designed to detect issues with the interpreter chip, I/O pins, RAM, and a few other elements. The code is designed to be as thorough as possible. However, if you cannot get it onto the module, then it is beyond the capabilities of this tester.

Internal/External Testing

The first thing that needs to happen is you have to tell the editor which Stamp it is testing. This is done by selecting the appropriate Stamp Directive from the toolbar or menu. The reason this is important is that the test code uses conditional compilation to set up different parameters and code blocks that are different for the various models. If you don't change the Stamp directive, you will be instructed to do so when you download the program and the editor detects a different model.

Bear in mind there is a verbose mode and a non-verbose mode. Parallax manufacturing uses the non-verbose mode for speed; tech support uses the verbose mode to see exactly what is happening during a test. These modes are set by a special constant toward the beginning of the code. The default is to use verbose mode which takes slightly longer to run, but gives details of each test performed on that module.

Once the code has been downloaded to the target module, it does the following:

- The *OUTS* register is checked for integrity, so it can be used as a counter for the RAM test.
- Variable RAM is tested.
- If the module has scratchpad RAM, it is tested.
- I/O pin drivers are tested.
- I/O pins are tested via an external RC circuit.

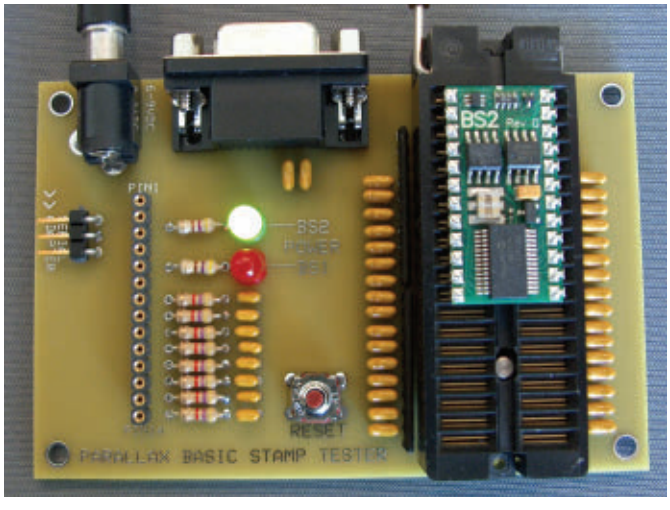
What's Going On in There?

The *OUTS* register is checked first because in order to test RAM, we need some way to keep track of the address. However, we're essentially destroying RAM, so we can't create a variable. Besides that, we need to do a complete test. The status of each test is shown on the Debug screen in verbose mode. Once variable RAM is tested, SPRAM is tested (if available). The EEPROM is not tested except for verification of the code download.

The I/O pin drivers are read back by the input register to verify that each pin reads what it is set to in the *OUTS* register. This is our loopback test. This is visually seen by a pattern of ones and zeros also on the debug screen.

Finally, each pin is tested using an *RCTIME* test with an external RC circuit. There are actually several ways a pin can fail, and the last two tests are designed to catch them all. This test ensures that each pin is within spec and is fully connected externally to the module (no broken traces or bad solder joints). The values for the *RCTIME* test are shown on the debug screen, along with a pass/fail indication.

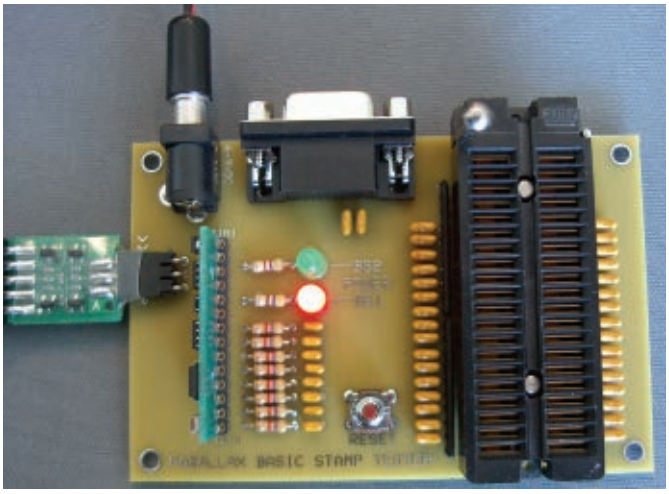
During development of the code, I was trying to find a clever way to determine if a BS2p40 was connected. I had a few choices since there is no separate directive for 24- and 40-pin BS2p modules. I finally used the fact that on 24-pin modules, the AUX pins are internally pulled up. This is a reasonable method for determining whether we have 16 or 32 I/O pins to test, and so the code can reliably detect a BS2p40 and tests all 32 I/O pins.



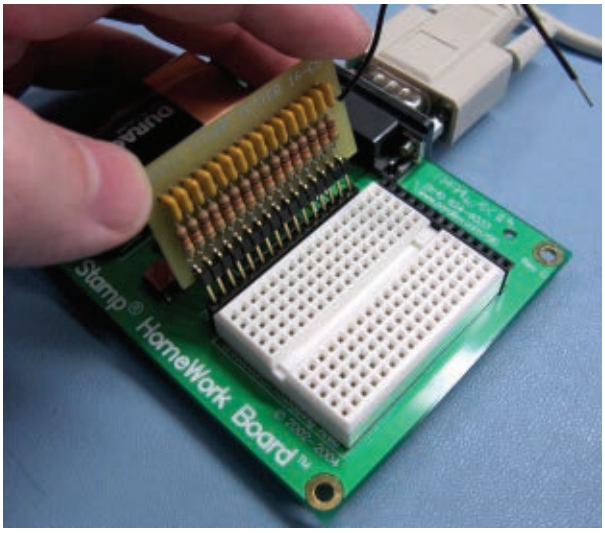
Let the Testing Begin

Okay, let's grab our module tester and drop in a Stamp to test.

■ **FIGURE 13.** In the example, a BS2 was loaded onto the tester. Notice the top LED lights. This is an indication that the onboard regulator on the module is working. The LED should light when the ZIF socket is closed. If we now connect our serial cable or USB-to-RS-232, we can download the test code and see what the status of this module is.



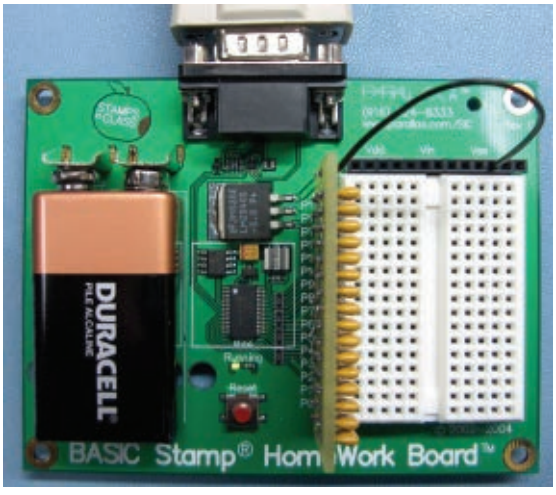
■ **FIGURE 14.** In this example, a BS1 is installed in the socket on the left and a BS1 serial adapter is connected to download the BS1 test code. In this case, the lower LED indicates the BS1 regulator has power. Note: Due to architectural differences between the Stamp 1 and Stamp 2 line, there is a different program (and, as you can see, a different socket) for testing the BS1 module. You must also still use the BS1 serial adapter.



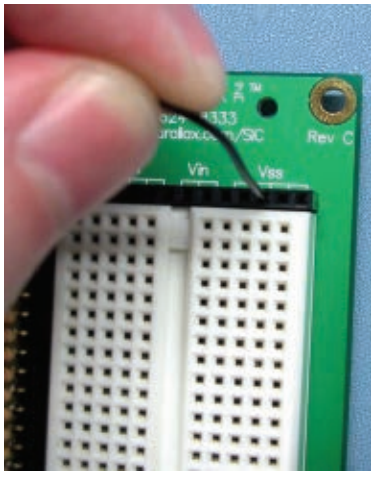
■ **FIGURE 15.** The card tester plugs in as follows.

Testing the Exceptions

In the following examples, we'll be testing a HomeWork board which includes a surface-mounted Stamp 2 installed on it. For this, we'll use the card tester since it can connect to the 16-pin SIP socket on the board, connecting to all 16 I/O pins and providing the RC circuit required by the test code.

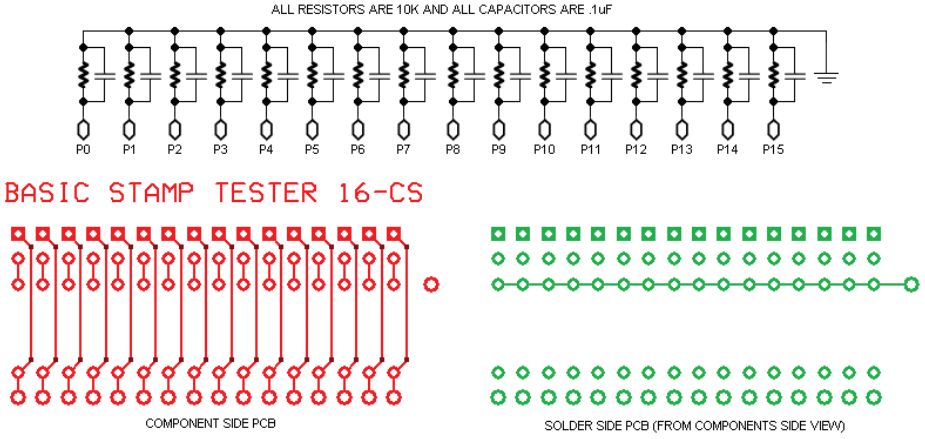


■ **FIGURE 17.** Here, the HomeWork board is ready for testing. For those wondering about the built-in series resistors on it, they do not affect the overall resistance in the RC circuit enough to alter the test results adversely.



■ **FIGURE 16.** If you installed the optional grounding wire, you can connect it to the VSS connection on the board.

■ **Stamp card tester schematic.**



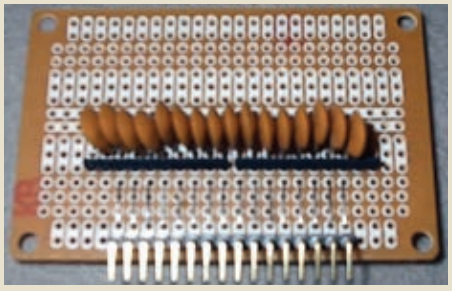
Building the Tester On a Budget

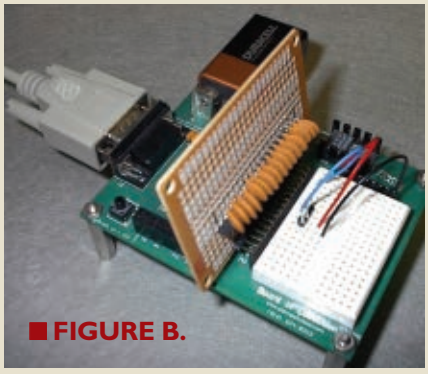
So, you want to build one of these little gems, but don't want to pay for three mini-boards ... understandable. The average hobbyist only needs one anyway, right? Before I started at Parallax, I had already built my own test board based on a discussion in the Parallax support/discussion forums.

Figure A is my home-brew version which later became the board discussed here. All of the parts were obtained from my local RadioShack, including the solder ring board itself.

Figure B is a shot of the tester being used on a Board of Education. Using the card version means if you don't build the module tester, you can still test 24-pin Stamp modules on a BOE.

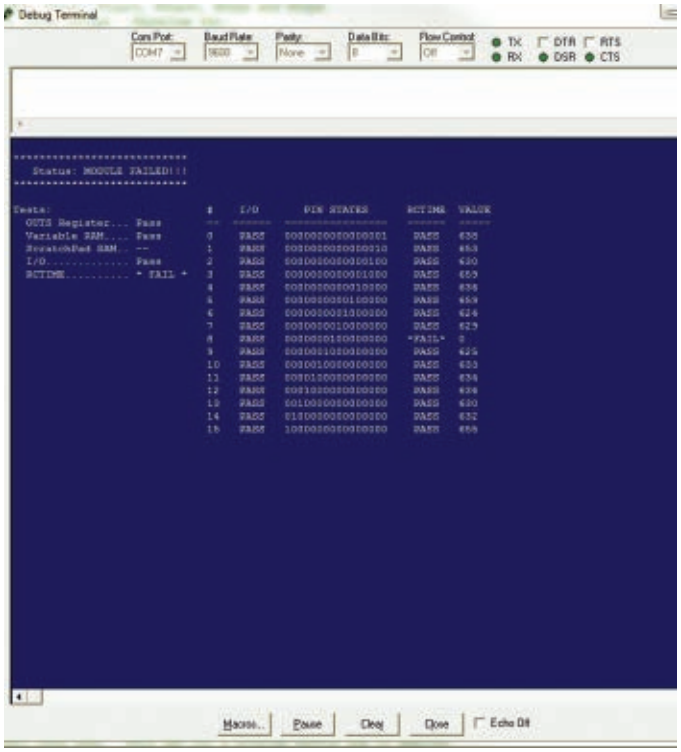
■ **FIGURE A.**



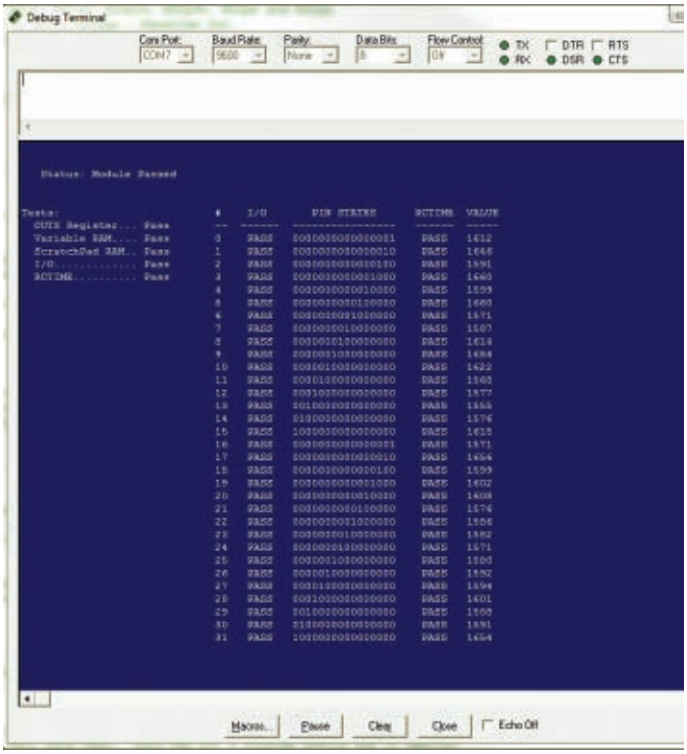


■ **FIGURE B.**

Now, you can test all those BASIC Stamp modules you have on your bench, ensuring they are reliable and up to the task of driving your next project. **NV**



Verbose output of BS2 (failed due to a bad I/O pin).



Verbose output of BS2p40 (passed).

MakerPlot – Part 9
The DIY Software Kit

By John Gavlik
and Martin Hebel

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com/index.php?/magazine/article/june2014_MakerPlot**.

This MakerPlot article is about Event Codes. Event Codes are the instructions that make every switch, button, and textbox control an Interface to do what you want it to do. Event Codes get executed whenever you click on a control (an external event) or when an internal event happens to cause an action by the control — like an alarm going off when an analog value is above or below the set levels. Event Codes consist of one or more MakerPlot instructions, and every control that reacts to internal or external stimulus has to have some form of Event Code.

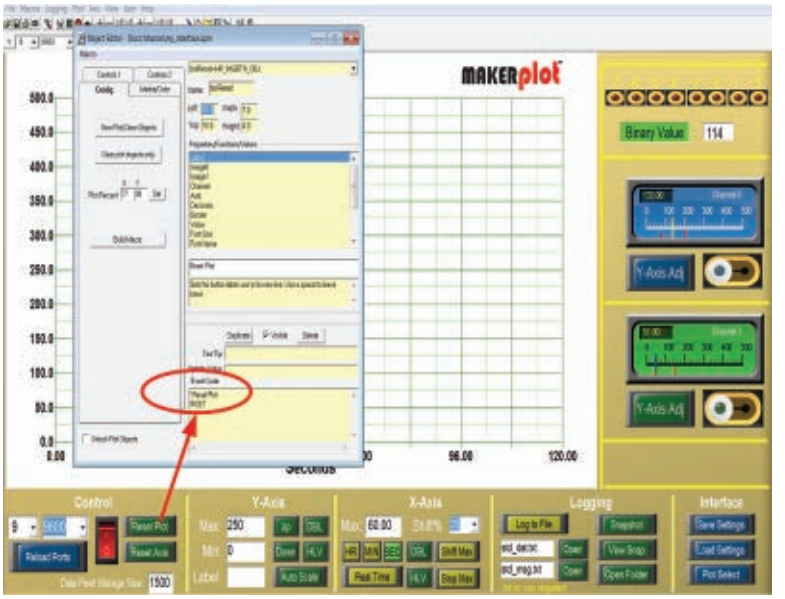


Figure 1. Reset Plot Button Event Code.

In our last article, we showed you how to build a custom Interface called *My_Interface.spm* using meters, switches, buttons, and textboxes that consist of "graphics only" controls at this point. Without Event Codes, these controls can't do anything. For example, if you click on a button, nothing will happen. This article will fill in the blanks with Event Codes for each of the controls so they will actually work and — more importantly — to instruct you how to do it when you create your own Interfaces. If you already have MakerPlot installed, you can follow along. If you haven't already done so, you can download a free 30 day trial copy of MakerPlot from **www.makerplot.com**. If you like what you see and what it does, ***you can order it from the NV Webstore at a discounted price***. Let's get going.

Event Code Basics

MakerPlot Event Codes are the instructions for programming the controls that populate any Interface. The best way to learn any programming language (IMHO) is to see what others have done with it. Following our own advice, we want to begin our Event Code lesson by showing you some fundamental uses of it to make meters, switches, and buttons do things.

To begin, load the *My_Interface.spm* and right-click on the Reset Plot button to bring up the Object Editor. **Figure 1** displays the Event Code for this button. As you can see, it's simply one instruction (*!RSET*), and comments are prefaced by a single quote as in *'Reset Plot* above the instruction. When the Reset Plot button is clicked, the *!RSET* instruction is executed which clears the plot area and sets the plot to time zero.

What's most important to realize is that you have to enter Event Codes into each control; they don't appear by themselves. Another important point is the exclamation point (**!**) prefix to each instruction. This tells MakerPlot that what follows is one of its instructions. **Figure 2** is

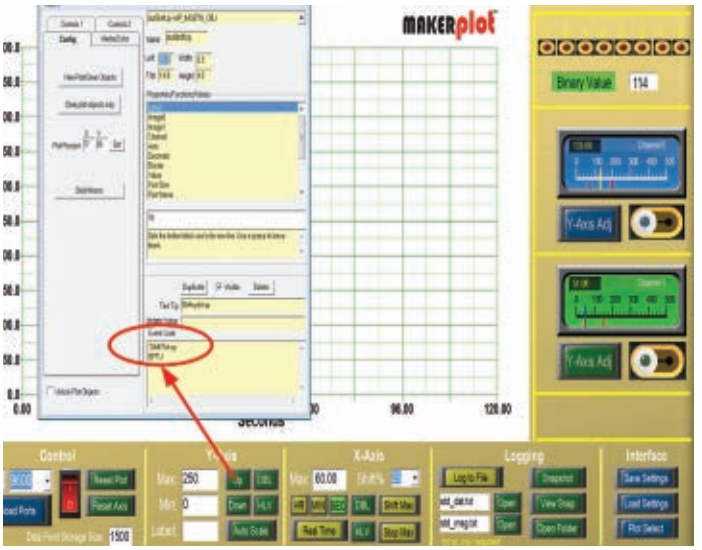


Figure 2. Y axis up button Event Code.

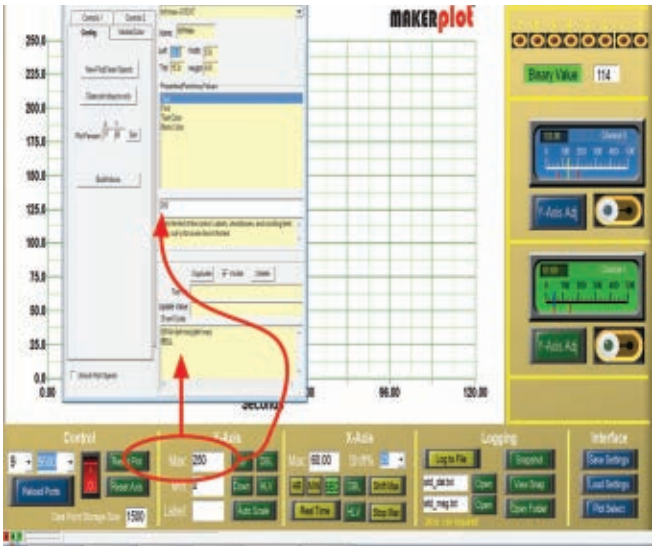


Figure 3. Y axis max value Event Code.

another example of a single instruction Event Code (*!SFTU*). This one is for the Y Axis "shift plot" up button. When it's clicked, the plot line values are shifted up by a defined amount. These are examples of single instruction Event Codes, but for many controls this is not enough.

Event Code Variables

As an example of a more complex Event Code, refer to **Figure 3** where we've right-clicked on the Y Axis Max Textbox and brought up the Object Editor listing for it. Instead of just stand-alone instructions, this Event Code has variables associated with it, as well:

```
!SPAN (txYmin), (txYmax)
!BELL
```

Here, *txYmin* represents the value currently in the Min textbox (0), and *txYmax* is equal to 250 (max). You can see the 250 value in the Object Editor; this is the same 250 value in the Max text box in the Y axis menu. With this particular Interface, the user can manually adjust these values by keying them into the Min and Max text boxes and pushing the Enter key; in doing that, basically this is what happens:

```
txYmin = Min textbox value
txymax = Max textbox value
```

Every time a new value is keyed into either the Min or Max text boxes, the Event Code for each one is executed and the Y axis is adjusted accordingly. Another button that uses these same variables is the Reset Axis button in the Control menu group (**Figure 4**). Its Event Code looks like this:

```
' Reset Y
!SPAN (txtYmin),(txtYmax)
!TMIN 0
!TMAX (txtXmax)
```

Notice that two other variables for the X axis (time) are also introduced. *!TMIN 0* sets the starting time of the plot to zero seconds and *!TMAX* sets the maximum time to *txtXmax* — which happens to be 60 — as that's what's currently entered in the Max textbox. So, when the Reset Axis button is clicked, the X and Y axes are set to these variables.

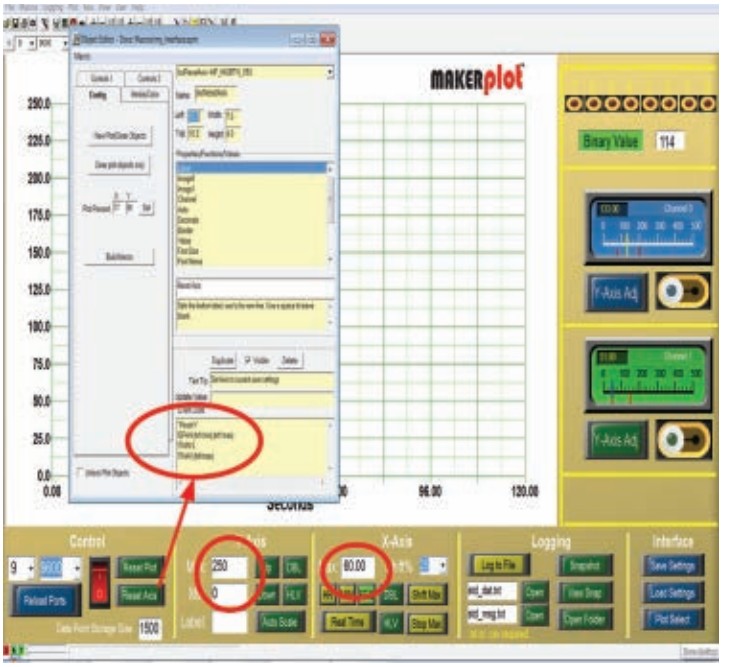


Figure 4. Reset axis Event Code.

Figure 5. Y axis adj Event Code.

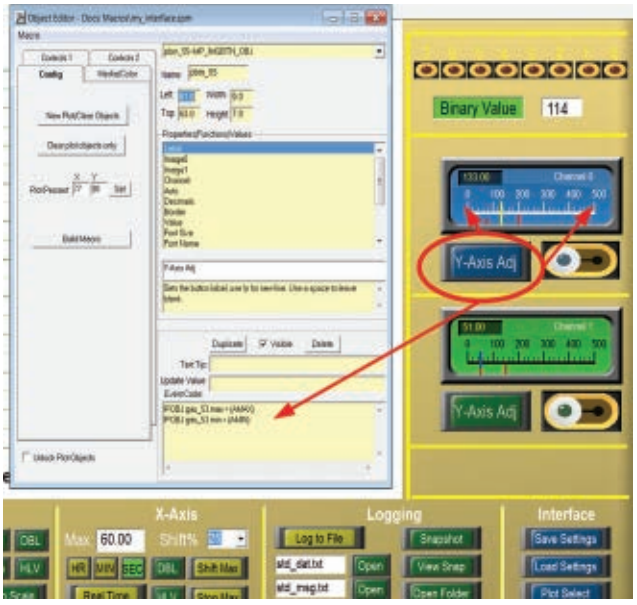
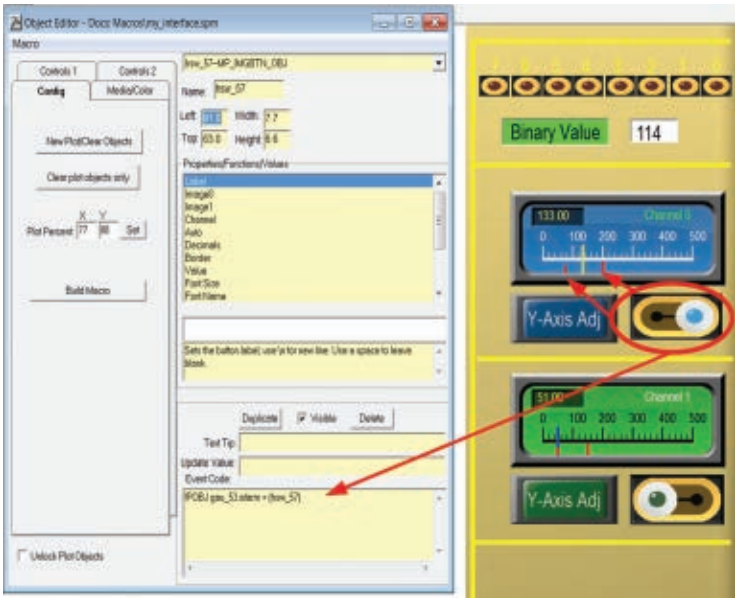


Figure 6. Meter alarm control Event Code.



Linking Event Code in One Control to Affect Another Control

Now, let's get to the controls that are on our custom Interface — *My_Interface.spm* — to show you how they work. Right-clicking on the top meter's Y Axis Adj button brings up the following Event Code:

```
!POBJ gau_53.max = (AMAX)
!POBJ gau_53.min = (AMIN)
```

Let's break this down. Refer to **Figure 5** for illustration.

- *!POBJ* is the MakerPlot "plot object" instruction.
- *gau_53* is the name of the top meter.
- *gau_53.max* is the meter's maximum range scale setting.
- *gau_53.min* is the meter's minimum range scale setting
- *AMAX* is the current Y scale maximum set in the Y axis Max textbox.
- *AMIN* is the current Y scale minimum set in the Y axis Min textbox.

So, when the Y Axis Adj button is clicked, this Event Code sets the meter range to the *AMIN* and *AMAX* values, which are 0 and 500 in this example. Just as important, what we're doing is linking one control (the Y Axis Adj) to affect another control (the top meter).

Now, let's look at how the alarm slider switch controls the meter's audio alarm condition. **Figure 6** illustrates the Event Code and the related actions. This one is simpler in that it only has one instruction:

```
!POBJ gau_53.alarm = (hsw_57)
```

- *!POBJ* is the MakerPlot plot object instruction.
- *gau_53* is the name of the top meter.
- *gau_53.alarm* is the name of the top meter's alarm state (ON or OFF, 1 or 0) which is set equal to the value of *hsw_57* as defined by the parenthesis ( ).
- *hsw_57* is the horizontal switch in question that has an ON or OFF state.

These are just a few Event Code examples as each control is different. However, it's all logical once you get the hang of how MakerPlot creates and parses the Event Codes. The full Event Code instruction set is at **www.makerplot.com** at the menu item Control Instructions. There are many more examples in the MakerPlot Guide which is also a menu item. Finally, there is a MakerPlot Video Tutorial in the Maker series entitled Event Codes, so check this out as well (**Maker Videos ➔ Event Codes**).

Object Properties Dropdown Menus

If you right-click on nearly any control object, it will bring up a menu for that control as in **Figure 7**. This is for LED 7. Nearly every property for this control is listed in the dropdown menu, and state 0 is highlighted

as an example.

Every LED control has two states: OFF is represented by state 0, and ON is represented by state 1. Each state has choices for image and color. We originally chose red LEDs to represent the digital data, but the color and LED image itself (there are several choices) can be altered by means of the dropdown menu. For example, you could choose a green color for the OFF state and a blue color for the ON state to replace the red colors. You can even choose a different LED style entirely. The point is it's easy to make changes to the controls using the right-click dropdown menu for it.

Once again, each control has its own set of properties (as illustrated in **Figure 8**) for the horizontal meter just below the string of LEDs. Here, we've highlighted the color choices for the meter background. Clicking on the color choice will change the meter background as in **Figure 9** where the blue background was changed to orange. It's that simple!

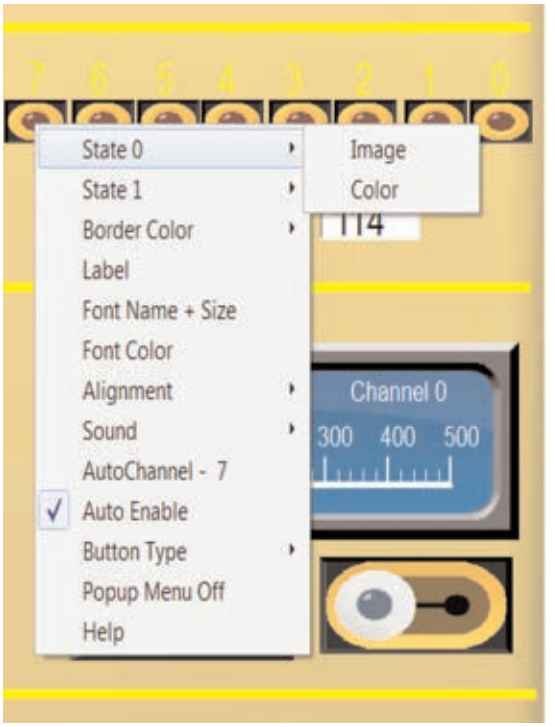


Figure 7. LED 7 dropdown menu.

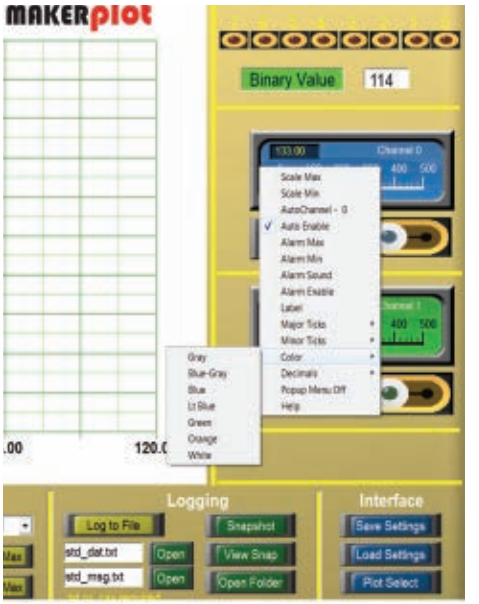


Figure 8. Meter dropdown menu.

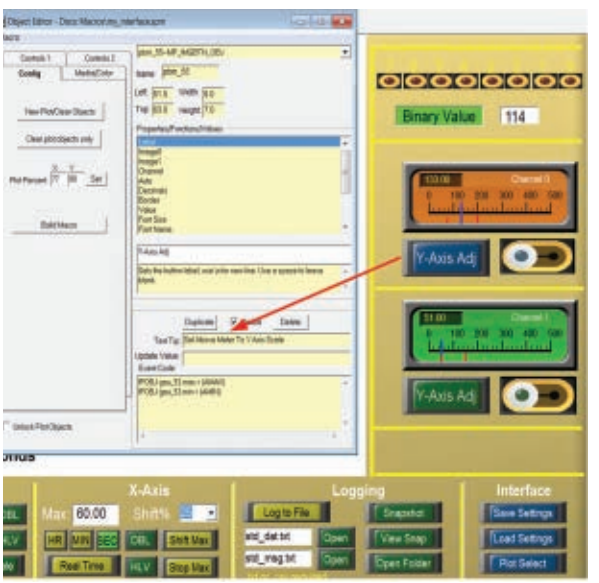


Figure 10. Object Editor for Y axis adj.

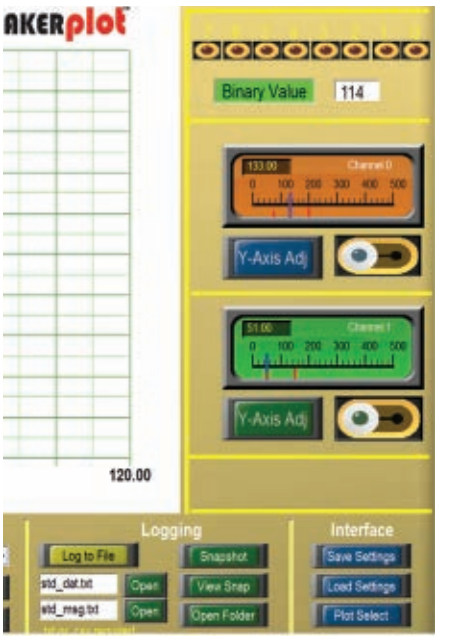


Figure 9. Meter color change to orange.

Back to the Object Editor

While the dropdown menus are great for adjusting most control properties, the more complete way is to use the Object Editor. As before, to bring up the Object Editor right-click on the top Y Axis Adj button (for this example); all the properties are displayed as in **Figure 10**. The Object Editor displays everything about the control including elements that the dropdown menus don't address, like the Text Tip. Before we entered the Text Tip (the arrow is pointing at it in **Figure 10**), there was none. Now, if you mouse over the Y-Axis Adj button, the Text Tip will appear. Notice that the Event Code that was described earlier is also shown.

The Object Editor is quite an important MakerPlot tool for naming, positioning, sizing, and configuring each control object. It's so extensive, in fact, that space does not permit going into it more deeply. There are two videos in the Object Editor on the MakerPlot website that explain

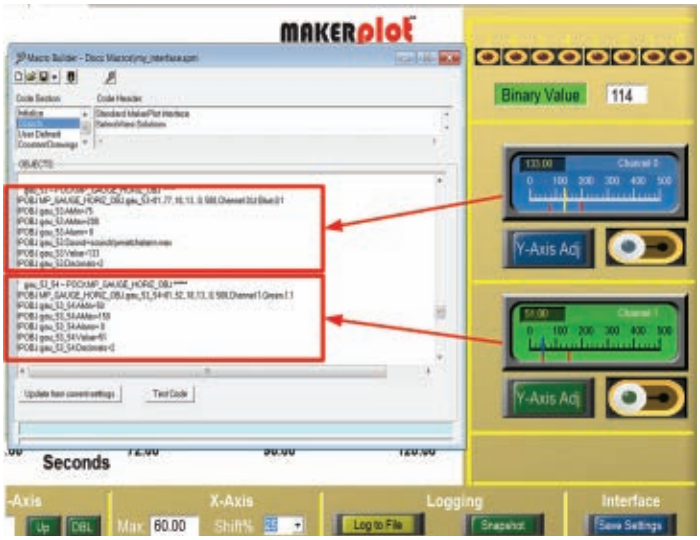


Figure 11. Macro Builder listing.

Figure 12. Macro Builder listing for alarm switches.

most of its functions. There's also the 200+ page guide.

The Macro Builder

The job of building controls falls to the Object Editor, and it creates the individual instructions and Events Codes for each object. In MakerPlot speak, we call these Macros, which are really nothing more than instruction lists for all controls on the Interface. It's the Macro Builder that organizes and maintains these instruction lists, including all relevant variables under the Interface's file name. The Macro Builder is also where changes to an Interface control — like adding a Text Tip — can occur and be saved.

By way of example, **Figure 11** shows the MakerPlot instructions for two horizontal meters. These instructions were automatically created in the Macro Builder as the meters were being built. Notice how each instruction sets itself equal to a variable for the meter's characteristics:

Top Meter

```
'    gau_53 — POCX:MP_GAUGE_HORIZ_OBJ *****
!POBJ MP_GAUGE_HORIZ_OBJ.gau_53=
81.,77.,18.,13., 0, 500,Channel 0,Lt Blue,0,1
!POBJ gau_53.AMin=75
!POBJ gau_53.AMax=200
!POBJ gau_53.Alarm= 0
!POBJ gau_53.Sound=sounds\wwatchalarm.wav
!POBJ gau_53.Value=133
!POBJ gau_53.Decimals=2
```

Bottom Meter

```
'    gau_53_54 — POCX:MP_GAUGE_HORIZ_OBJ *****
!POBJ MP_GAUGE_HORIZ_OBJ.gau_53_54=
81.,52.,18.,13., 0, 500,Channel 1,Green,1,1
!POBJ gau_53_54.AMin=50
!POBJ gau_53_54.AMax=150
!POBJ gau_53_54.Alarm= 0
!POBJ gau_53.Sound=sounds\beep.wav
!POBJ gau_53_54.Value=51
!POBJ gau_53_54.Decimals=2
```

Also notice that the meters have no Event Codes associated with them. The reason is that the meters do not respond to any external stimulus like a mouse click; instead, they are affected by the slider switches below them that change the alarm states from 0 to 1 or vice versa, depending on the state of the slider switch. **Figure 12** shows their Macro Builder listing. I've repeated it here for clarity, highlighting the Event Code that sets the alarm logic state to equal the logic state of the slider switch — which are *hsw_57* (top) and *hsw_58* (bottom).

Therefore, when the Alarm slider switch is clicked, it changes state from 1 to 0 or vice versa, and the corresponding meter alarm variable is changed accordingly. Hopefully, it's making a bit more sense now as far as how the Event Code in one control affects the operation of another control:

Top Meter Alarm ON-OFF Switch

```
'    hsw_57 — POCX:MP_IMGBTN_OBJ *****
!POBJ MP_IMGBTN_OBJ.hsw_57=91.,63.,7.7,6.6,
,0,dev\slide-sw\b_slider_blu_h_0.gif,dev\
slide-sw\b_slider_blu_h_1.gif,ON-OFF,1
!POBJ hsw_57.Sound=sw_slide2.wav
```

```
'— Event Code
!POBJ hsw_57.C=!POBJ gau_53.alarm = (hsw_57)
```

Bottom Meter Alarm ON-OFF Switch

```
'    hsw_58 — POCX:MP_IMGBTN_OBJ *****
!POBJ MP_IMGBTN_OBJ.hsw_58=91.,38.,7.9,7.2,
,0,dev\slide-sw\b_slider_grn_h_0.gif,dev\
slide-sw\b_slider_grn_h_1.gif,ON-OFF,1
!POBJ hsw_58.Sound=sw_slide2.wav
'— Event Code
!POBJ hsw_58.C=!POBJ gau_53_54.alarm =
(hsw_58)
```

The Macro Builder is an important MakerPlot tool and there is a video on its operation at **Maker Videos ➔ Macro Builder.**

Conclusion

We hope by now that you're getting more familiar with MakerPlot's inner workings since — like any programming language — the devil is in the details. We've made it as painless as possible to learn by offering video tutorials in addition to our extensive guide.

The beauty of MakerPlot is that you can start out with it at the off-the-shelf level with the Interfaces that come standard with the software. Then, if you're so inclined, you can customize these Interfaces to your liking. Either way, MakerPlot will make your data plotting, logging, and analysis much easier and relevant.

What we've shown you in these last two articles is how to create and configure the various controls on the Interface directly on the PC. What we'll show you in the next article is how to create them DIRECTLY from your micro, which means that you can build Interfaces "on the fly" as needed. This is really a neat feature since you can change the look and feel of the Interface to match your micro's application.

That's all for now, so just remember: Got Data – MakerPlot It! **NV**

Control Instructions

You can find the entire MakerPlot control instruction set on the website. Control instructions can be used to configure and control nearly all aspects of MakerPlot. They may be sent from the controller (used in macros) in Event Code or just manually entered in the Log Window Command Line Interface (CLI). Refer to the guide for the complete Control Instructions Summary starting in Section 14.

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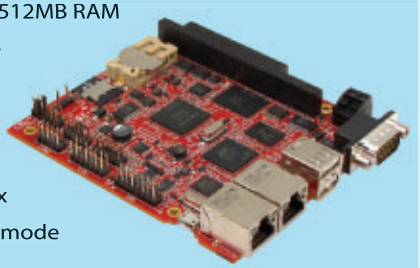

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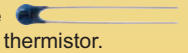

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■ BY JOE PARDUE

The Arduino Classroom
Arduino 101 — Chapter 6: Analog Input

Last time, we were introduced to the concepts of analog versus digital signals where we discovered that digital signals are made from two discrete voltages (in our case, +5V and 0V) and analog signals can take any voltage (in our case, on a continuum from +5V to 0V). We learned how to generate analog signals using PWM and also about the Arduino serial monitor and how to use that to communicate between a PC and the Arduino. In this chapter, we will learn about inputting analog signals using the ADC (analog-to-digital converter) built into the Arduino. We will also get an introduction to some basic electrical concepts which will help us to understand what it is we are inputting. First, though, let's learn some more serial communication techniques.

Sending Commands and Data

The computer on the Arduino board is an ATmega328 microcontroller and — as the name indicates — it is intended to control things. Sometimes a microcontroller is entirely embedded into a system such as a car engine where it might do something like sensing oxygen and actuating an air intake valve. Other times, it is used in a system where it requires human user input — like in a microwave oven where it senses button presses and uses that human input to set the cooking time.

In our last lab, we saw how to use a PC to send data to the Arduino to set the angle on a servomotor, but there could be many different things we'd like to make a servomotor do. For instance, if the servomotor is controlling a camera-pointing system on a robot, we might want to have the camera sweep across an area beginning at a certain position and ending at another position. Plus, we might want the sweep to occur at a certain speed.

Here, we have three different actions to control on the servo, and each action is associated with a specific number. We might want to have the sweep speed be something between the slowest speed at 0 and the fastest speed at 100. Then, we might want to make the servo start at 45°, move to 135°, and do that at a medium speed of 50. If we want to control this action from a PC, then we will need four commands: one to set the start position; one to set the end position; one to set the velocity; and one to tell it to do the sweep.

We've learned how to send numbers; now, let's learn how to send commands along with those numbers.

In the last chapter, we looked at how to send a number from the PC serial monitor to the Arduino so that it could use that number to set the angle of a servo. We saw that if we received a string of characters that represent a number (such as "123") that we could use the following statement to convert the string to an integer:

```
int n = readString.toInt();  //convert readString into a number
```

The *readString.toInt()* function is very useful when we send it the characters for a number. However, if we send it non-numeric characters (like 'a' or '!'), it doesn't know what to do with them and the function returns 0. [You should remember this if you want to receive a 0 as a valid number, since you might actually be receiving a 0 as an error indication.]

Let's look at the situation where we want to send a command to the Arduino that contains a number. When the only thing we were sending to the Arduino was a number representing the angle, that was no problem. So, what if we also want to send a number representing the velocity we want the pointer to move, or a number that represents the angle we want the motion to start from, or another number for the angle where the motion ends?

Here we have three separate numbers, so we'll need some way to link them to a command for the action associated with the number. For velocity, let's use 'v' to precede the number: *vxxx* where *xxx* is 0 to 100 (0 is stopped and 100 is the maximum speed). For the start angle, we will use 's' as *sxxx* where *xxx* is 0 to 180. For the end angle, we will use 'e' as *exxx* where *xxx* is also 0 to 180. This means that the Arduino will get the string *v123*, and must be able to separate the *v* as the velocity command

and the 123 as the speed for the pointer to move. To do this, we receive the string *v123*, then we get the first character in that string into a 'command' variable using the *readString.charAt()* function as follows:

```
command = readString.charAt(0);
     // get the first character
```

The parameter for *.charAt* tells the function which character to get; in our case, it's the first character that is in the 0 position in the string. [Remember that computers start counting at 0, not 1.] When we have the command set, then we can look at the character in the command to see what it is. We do this as follows:

```
if(command == 'v')// set the velocity
{
    // do what is needed to set the velocity
}
else if(command == 's')// set the start angle
{
    // do what is needed to set the start angle
}
else if(command == 'e')// set the e angle
{
    // do what is needed to set the end angle
}
```

We will call this technique a command parser. As you can see, we can parse as many separate commands as there are ASCII characters. [In a later chapter, we will learn to accept commands that are greater than a single character since it is much easier to remember what the command 'set end angle' does than 'e.']

Once we have identified the command and the code moves into the block [delimited by { and }] that deals with it, we need to extract the number that was sent following the command character. We do this by first reading the rest of the command string from the second position (position 1; remember we started counting at 0) using the *readString.subString()* function as follows:

```
String temp;

temp = readString.substring(1);
    // get the rest of the string
velocity = temp.toInt();
    // convert the string to an integer
```

In Lab 1, we will use this to control motion by setting a start and end angle, and a velocity for the pointer to move. This sort of action is used in a variety of real world situations, like controlling where a camera is pointed or the position and speed of a machine tool.

Voltage, Current, and Resistance

The term 'analog input' refers to using a computer to sense analog (continuous) information from the environment. We often do this by sensing voltage where it is an indicator of some continuous parameter in the environment that we want to measure. When we measure light, temperature, or sound, for instance, we have an electrical device or circuit that converts the light, temperature, or sound to an equivalent voltage. Then, we measure that voltage with a peripheral in our microcontroller called an **ADC (analog-to-digital converter)**. We then use some sort of calibration value to map the voltage to the parameter being measured.

We might have a temperature sensor that measures from -40°C to +150°C by outputting voltage from 0.1V to 2.0V. For this example, we have about 0.17V per degree Celsius, so we could write a little algorithm that would read the voltage and report the temperature in Celsius or — with another line of code — Fahrenheit.

In Chapter 2, we learned that we could light an LED by connecting the long leg to +5 volts, the short leg to one side of a resistor, and the other side of that resistor to ground. In that illustration, we used a 1,000W resistor which functions to limit the amount of electrical current that moves through the LED. If we connected the LED directly to +5 and 0, the current would be so great that the LED would overheat and burn out. For us to understand analog input, we need to understand a bit more about electricity than we have seen so far.

Electric Measurements

When we want to bake a cake, we follow a recipe that will say something like we need two cups of this, a teaspoon of that, a dash of something else, baked at some temperature for some time. If we want to have a cake that is edible, we need to know what the measurements mean. What are cups, teaspoons, dashes, degrees Fahrenheit, and minutes? Likewise, to play with electricity we need to know some electrical measurements.

There are three things that we measure when we first learn about electricity: voltage, current, and resistance, with units in volts, amps, and ohms. Volts are a measure of electric potential (force — how hard the electricity is pushing); amps are a measure of electric current (how much of the electricity is moving through something); and ohms are a measure of opposition to electric current flow.

Electric Potential Difference = Voltage

We intuitively understand that if someone dumps a bucket of water off a 20 story building and it hits the sidewalk next to us, we are going to get splashed more than if someone standing next to us dumps that bucket of water from three feet up on the same spot. We use this fact every time we turn on a faucet. The water pipe is connected to a tank of water located higher up than our faucet: the higher the tank, the greater the water pressure.

Voltage is like water pressure, but electric 'pressure' does not come from gravity. It comes from the simple fact that electrons do not like each other and the more crowded they get, the madder they get, and the more determined they become to bust out and go somewhere

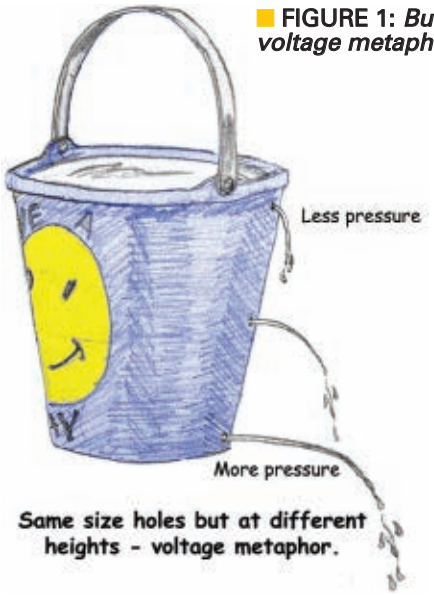


FIGURE 1: *Bucket voltage metaphor.*

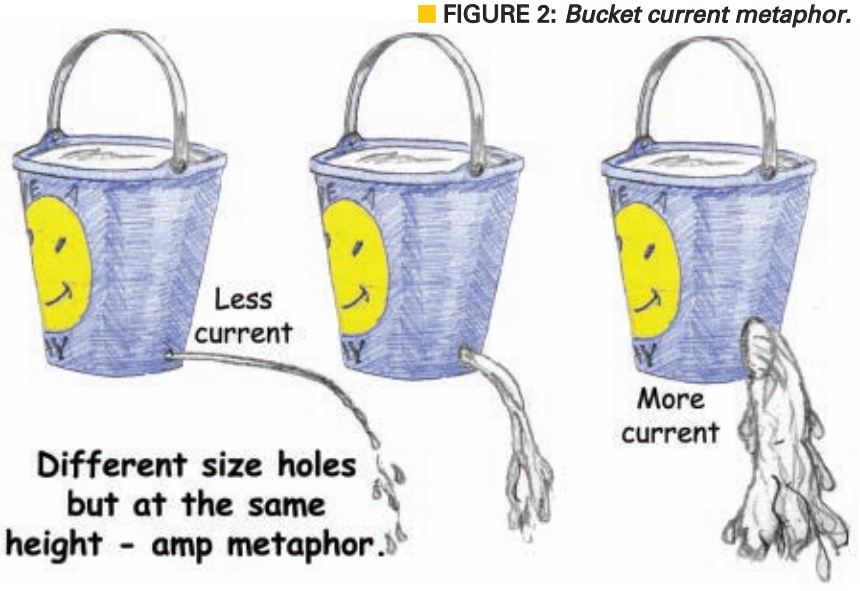


FIGURE 2: *Bucket current metaphor.*

with fewer electrons (hey, that's what quantum physicists say if you read between the lines). Areas with more electrons are said to have a higher electric potential relative to areas with fewer electrons. **Figure 1** shows this with holes at different depths along the side of a bucket. This potential difference (more electrons in one area and less in another) can be thought of as a force that pushes electrons from one place to another. Voltage is a measure of the electric potential difference between two areas that have different amounts of electrons. Water *will* run down hill if it *can* run down hill, and electrons *will* spread out from higher electron density regions to lower electron density regions if they *can* spread out.

Electric Current = Amps

We think of current as the amount of water moving past in a stream. The Gulf Stream, for example, has a lot more water moving along than what comes out of your bathroom faucet. A bolt of lightning has a lot more electrons moving past than the spark of static electricity your older brother applies to your ear after sliding his bunny slippers across the wool carpet in the hall on a dry day. The amount of electric current is referred to as amperes or amps. **Figure 2** uses the water bucket metaphor with larger holes allowing greater current. Pressure is the same, but as the holes get bigger you get a greater current.

Electric Resistance = Ohm (Ω)

For the water analogy, we can think of resistance as being caused by the diameter of the hole. Note that in **Figure 2** more current is due to different size holes — bigger hole, less resistance, more water.

For the resistors in the projects kit (available at the *NV* Webstore), the higher the number, the more the resistance. So, you can think about the 10K Ω resistors as having a smaller electric hole and thus passing less current than 1K Ω resistors which have a bigger hole and pass more current. Materials with low resistance are known as **conductors**, while materials with high resistance are known as **insulators**. Electrons move easily in some things such as copper wire (a good conductor), but are stopped cold by some things such as glass (a good insulator). Copper has very low resistance — jumper wires can have near zero ohms of resistance (about one ohm per 62 feet), while glass can have millions of ohms of resistance.

Ohm's Law

Georg Simon Ohm wrote a rule to account for observations of voltage (volts), current (amps), and resistance (ohms). We typically see this rule as voltage is equal to current times resistance:

Volts = Amps * Ohms
Voltage equals current times resistance.

A little algebra shows us that the equivalents are:

Amps = Volts/Ohms
Current equals voltage divided by resistance.

Ohms = Volts/Amps
Resistance equals voltage divided by current.

Now, let's confuse things a little bit and use the standard (SI) symbols for this:

V = IR *Voltage equals current times resistance.*

The confusion is that 'I' is the symbol for amps. This is what is used, so let's just go with it:

I = V/R
Current equals voltage divided by resistance.

R = V/I
Resistance equals voltage divided by current.

With this law, if you know any two of the variables, you can solve for the third unknown variable. This comes in handy when, for instance, you want to specify the resistor for an LED. Let's say that you will be powering at 3.3V and the datasheet says the LED is most efficient when passing 15 mA of current. You solve the resistance formula:

R = V/I
R = 3.3/.015
R = 220 Ω

Since 220 Ω is a standard resistor size, we can easily get the exact resistor needed. If we use 1K Ω resistors and have 5V power, the current can be found with:

I = V/R
I = 5/1000
I = 0.005 amps

While 5 mA (0.005 amps) is under-powering the LED, it is plenty bright. Since we may be using batteries, the lower current saves power and extends the battery life.

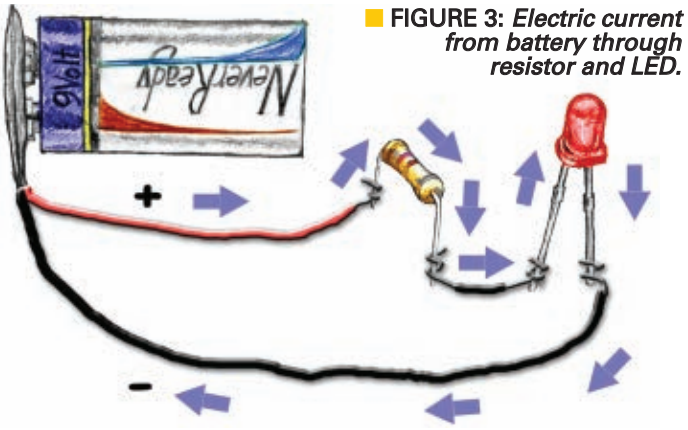


FIGURE 3: ***Electric current from battery through resistor and LED.***

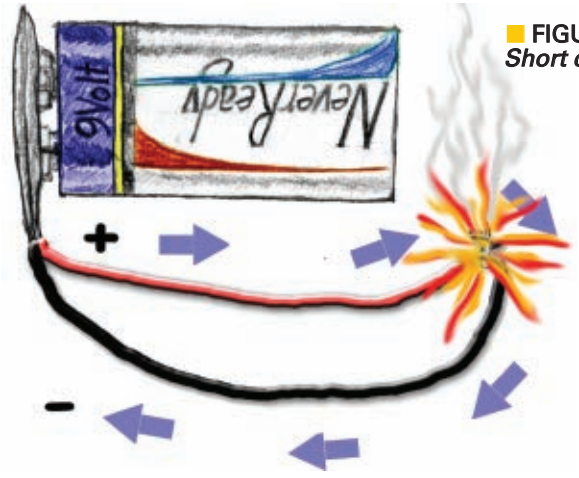


FIGURE 4: ***Short circuit.***

Circuits

We get electricity to do useful work by channeling it from devices that produce electric force (like generators and batteries), through devices that do electric work (like lights and motors), and then back to the device that created the force. That last part is critical. Circuit is just a fancy way of saying 'circle.' Electricity must run in a circle to be useful.

Figure 3 shows arrows marking the direction of conventional current from the higher voltage side of a nine volt battery (the positive terminal) through a resistor and an LED, back around to the lower voltage terminal of the battery. You've probably seen complex circuits on printed circuit board (PCBs) or as schematics, but no matter how complex it looks it can be simplified to: one part producing the force as a current; one part using that force to do work; and the circular electrical connection between them.

Short Circuits

If we connect a copper wire between the + and – terminals of a battery — 'short circuiting' them (as shown in **Figure 4**) — the current will rush through, doing a lot of work making the wire heat up and quickly depleting the chemicals in the battery that are creating the electric potential difference in the first place.

Don't try this experiment because not only will it deplete your battery, many batteries will heat up and possibly even explode when treated this way.

If you are doing Arduino experiments plugged into the USB port of your computer, you are using +5V supplied from the PC over the USB cable. If you short-circuit the + to the - (and if you are lucky), the USB protection circuits on the PC will detect the current rush and shut down your USB connection before something blows up. If you aren't lucky? Well, say bye bye to something expensive. The morale? Be careful not to short-circuit anything expensive, flammable, or with tendencies to explode — including you.

Voltage Across Resistance

Let's build a circuit that lets us play with Ohm's Law. We put eight 1K Ω resistors on a breadboard so that they are each connected in series; this yields 8K Ω in 1K Ω increments. Connect one end of this series to +5V and the other end to the GND as shown in **Figures 5**, **6**, and **7** that show the current and the voltage drop across this circuit.

This arrangement of resistors is called a **voltage divider** and allows us to access each cumulative resistance value from 0 to 1K, 2K, 3K, 4K, 5K, 6K, 7K, and 8K. [The illustrations also show the Arduino analog input pin 0 attached between the fifth and sixth resistors, counting up from the +0V. We will look at that in a minute]. Let's play

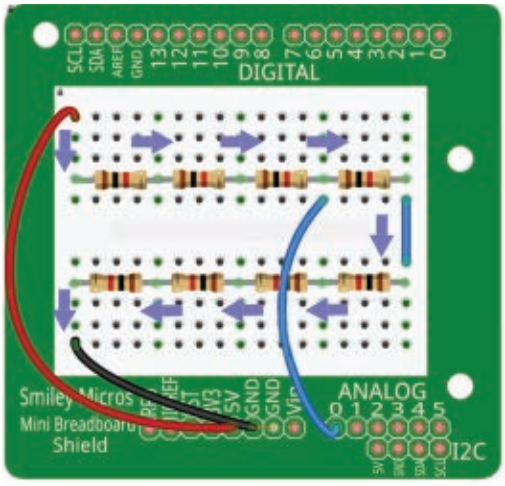


FIGURE 5: *Resistor series current.*

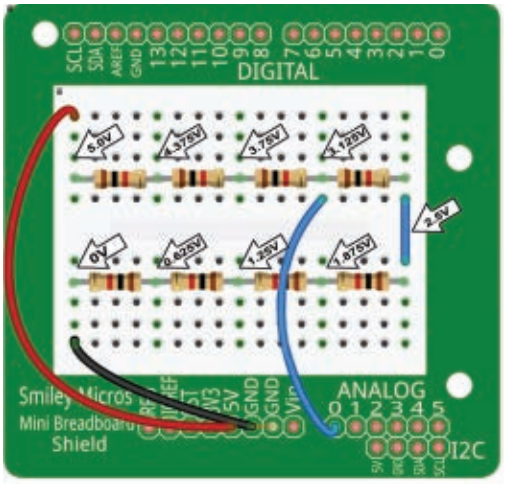
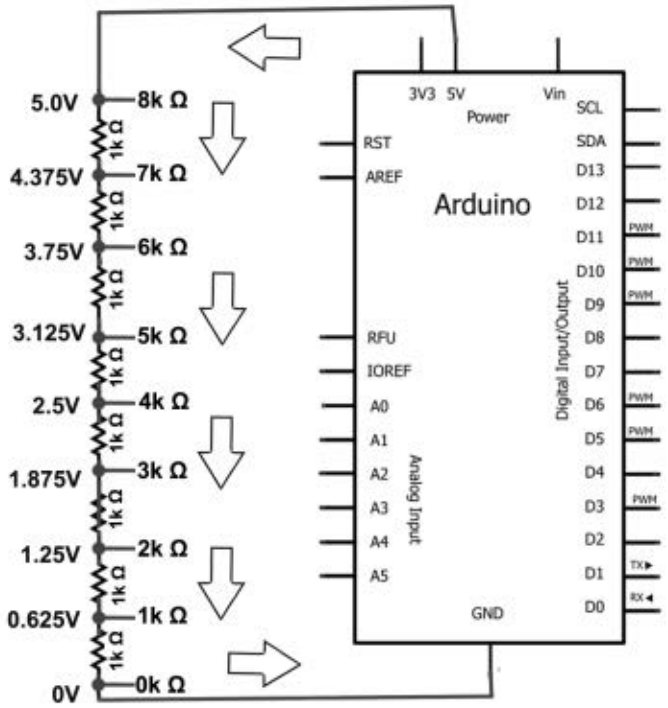


FIGURE 6: *Resistor series voltage .*

FIGURE 7: *Resistor series schematic.*



with Ohm's Law for a moment. We know that we have five volts and a total of 8K Ω resistance in our circuit. So, we can calculate the unknown variable which is current (I):

I = V/R
I = 5/8000 = 0.000625 amps

Take note that 0.000625 amps is the same as 0.625 milliamps, which we will usually show as 0.625 mA. So, we have 0.625 mA current passing through each of the eight resistors. Since each resistor is 1K Ω, we can solve Ohm's Law for the voltage across each resistor:

V = IR
V = 0.000625 * 1000 = 0.625 volts

So, theoretically, we should be able to measure the billed voltage between the fifth and sixth resistor above 0V (as shown in **Figure 6**), and it should conform to Ohm's Law where the total resistance of the five resistors is 5K Ω:

V = IR
V = 0.000625 * 5000 = 3.125 volts

Theoretically? We'll take a closer look at this law with some real world measurements in the labs, but first let's take a look at an Arduino function we will find very useful for when we get there.

The Arduino *map()* Function

We notice in nature that sometimes two separate variables may be proportional to each other (meaning that the two numbers correspond in size). For instance, we know that with a constant resistance, the higher voltages correspond to higher currents. In Lab 2, we will use different voltages to specify different servomotor angles. We will use ADC readings which range between 0 and 1023, and we will use these readings to set a proportional servo angle that ranges between 0 and 180.

Thus, if we have half the ADC reading (512), we can have half the servo angle (90). If we want to use the ADC reading of the voltage to specify the servo angle, then we would need to use the following formula:

Servo_angle/180 = ADC reading/1023

If we read ADC = 512, we can solve for the servo angle:

Servo_Angle/180 = 512/1023
Servo_Angle/180 = 0.5
180 * Servo_Angle/180 = 0.5 * 180
Servo_Angle = 90

We could easily write an algorithm to do this in the Arduino IDE, but we can also (which would be even easier) use the *map()* function which takes the parameters:

```
map(value, fromLow, fromHigh, toLow, toHigh)
```

So, given the information above, we write:

```
int value = 512;

map(value, 0, 1023, 0, 180);
if( value == 90)
{
       // do this
}
else
{
       // do that
}
```

In the above code snippet, the value would be mapped from 512 to 90, and the *//do this* block would run. We will use this in Lab 2 to map ADC readings to servo angles.

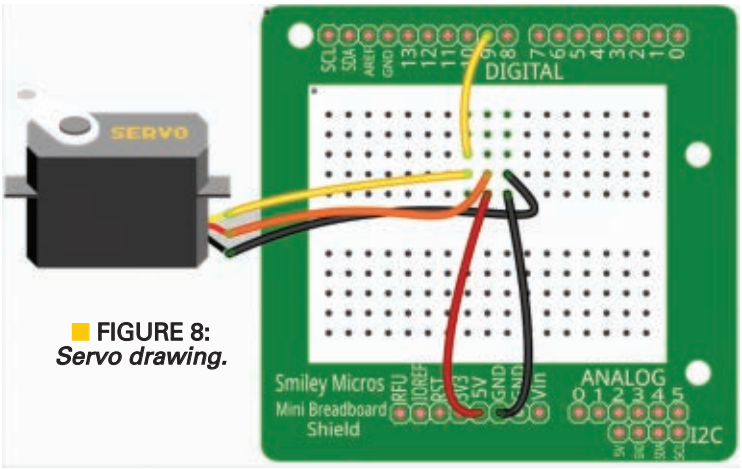


FIGURE 8: ***Servo drawing.***

Lab 1: Sending a Command Plus Data

This lab will use the same setup from the final one last month. The servo drawing in **Figure 8** is included here as a reminder of how to wire it up.

Parts required:
1 Arduino
1 USB cable
1 Arduino proto shield
1 Three-pin header
1 Mini servo motor

Estimated time for this lab:
30 minutes

Check off when complete:
❏ Wire the servomotor to the Arduino proto shield as shown in **Figure 8**.
❏ Load the *A101_ch6_servo_velocity.ino* program into the Arduino IDE. (The file is available at the article link.)

```
// Arduino_101_ch6_servo_velocity
// 3/26/14 Joe Pardue

#include <Servo.h>

// create servo object to control a servo
Servo myServo;

// Declare global variables
int startAngle,endAngle, velocity;
String readString;

void setup()
{
  myServo.attach(9);  //attaches the servo on
                      //pin 9 to the servo object

  // initialize the serial communication:
  Serial.begin(57600);
  //Serial.flush();
  Serial.println("Servo Angle Velocity 1.0");
  Serial.println("Use:");
  Serial.println("Send vxxx where xxx is 0 to 100
  to set velocity.");
  Serial.println("Send sxxx where xxx is 0 to 180
  for start angle");
  Serial.println("Send exxx where xxx is 0 to 180
  for end angle");
  Serial.println("Send g to move from start to
  end atvelocity");
}

void loop()
{
  char command;
  String temp;

  while (Serial.available()) {
    char c = Serial.read();  //gets one byte from
                             //serial buffer
    readString += c;         //makes the string
                             //readString
    delay(2);  //slow to allow buffer to fill
               //with next character
  }

  if(readString.length() > 0)
  {
    command = readString.charAt(0);

    if(command == 'v')// set the velocity
    {
      Serial.print("Set velocity to: ");
      temp = readString.substring(1);
      velocity = temp.toInt();
      Serial.println(velocity);
    }
    else if(command == 's')// set the start angle
    {
      Serial.print("Set start angle: ");
      temp = readString.substring(1);
      startAngle = temp.toInt();
      if(startAngle < 0) startAngle = 0;
      if(startAngle > 180) startAngle = 180;
      Serial.println(startAngle);
    }
    else if(command == 'e')// set the end angle
    {
      Serial.print("Set end angle: ");
      temp = readString.substring(1);
      endAngle = temp.toInt();
      if(endAngle < 0) endAngle = 0;
      if(endAngle > 180) endAngle = 180;
      Serial.println(endAngle);
    }
    else if(command == 'g')// move the pointer
    {
      if(startAngle < endAngle)
      {
        for(int i = startAngle ; i < endAngle;
        i++)
        {
          // 180 - i because the compass is
```

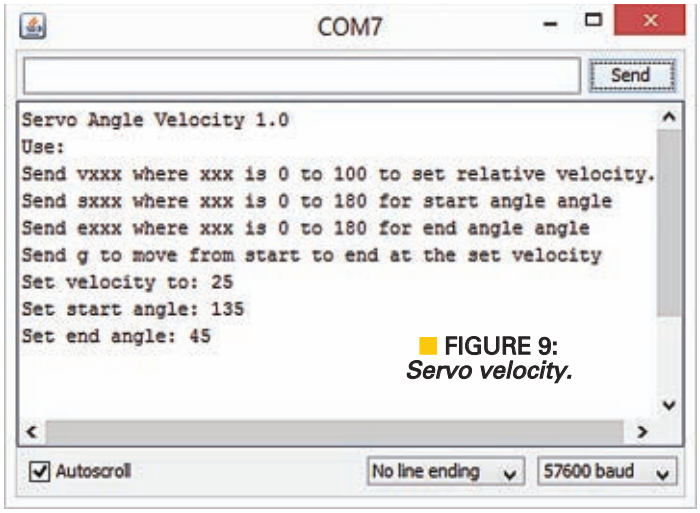


FIGURE 9: *Servo velocity.*

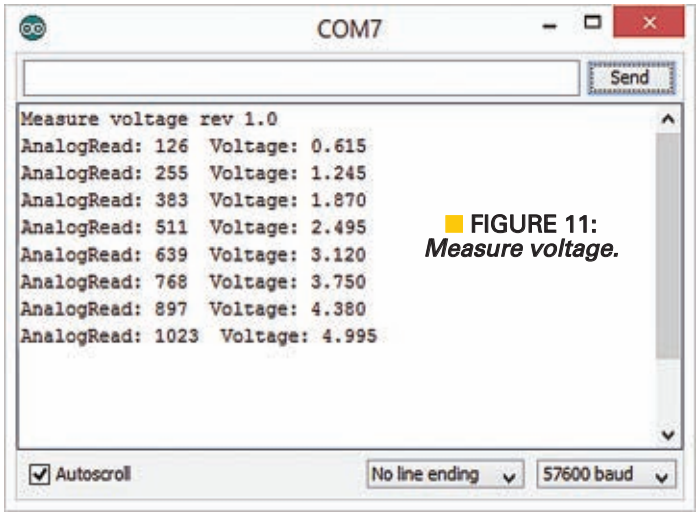


FIGURE 11: *Measure voltage.*

```
            //reversed
            myServo.write(180-i);
            delay(velocity);
          }
        }
        else
        {
            for(int i = startAngle ; i > endAngle;
            i—)
          {
            // 180 - i because the compass is
            //reversed
            myServo.write(180-i);
            delay(velocity);
          }
        }
      }
      else
      {
        Serial.println("Incorrect command
        character");
      }
     readString = ""; // clear out the string
    }
}
```

❑ Enter 'v25,' then 's135,' then 'e45,' then 'g,' and verify that you get the output shown in **Figure 9**.

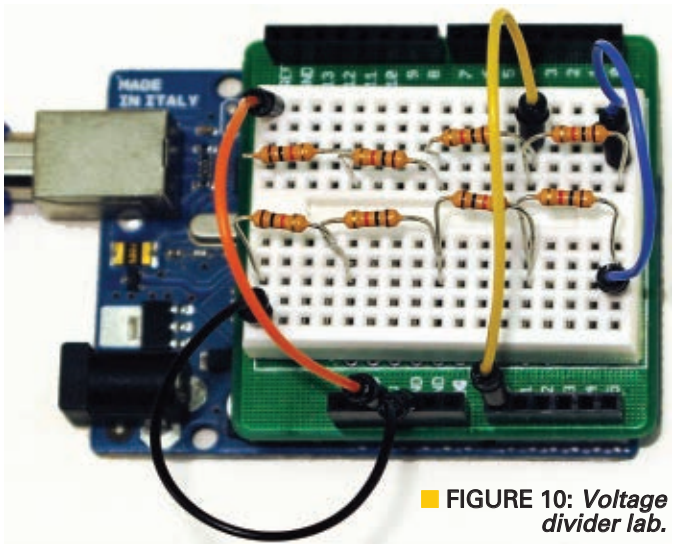


FIGURE 10: *Voltage divider lab.*

Lab 2: Voltage Divider

In **Figures 5**, **6**, and **7**, we saw the drawing and schematic for a circuit with eight of the 1K Ω resistors linked in series from +5V to GND, and we learned that the voltage across those resistors is equally divided among them since they are the same size. For this lab, let's verify what we learned by building the circuit (see those figures and the photo in **Figure 10**.) Note that the values derived from the Arduino ADC and subsequent calculations will not be precisely what we expect due to inaccuracies inherent in this setup, but they should be close.

Parts required:

1 Arduino
1 USB cable
1 Arduino proto shield
8 1K Ω resistors

Estimated time for this lab:

30 minutes

Check off when complete:

❑ Build the circuit shown in **Figures 5**, **6**, **7**, and **10**.
❑ Attach one end of a jumper to the Arduino analog input pin 0 as shown in the figures.
❑ Move the other end of the jumper to the breadboard holes corresponding to the connection between each resistor. To begin, plug the jumper into the hole where resistors 5 and 6 are connected as shown in **Figures 5**, **6**, and **10**.
❑ Load the *A101_ch6_voltage_divider.ino* program into the Arduino IDE (again at the article link):

```
// voltage_divider 3/31/14 Joe Pardue

int sensorPin = A0;   // analog input pin
int sensorValue = 0;  // store the analog input
value
```

```
void setup() {
  Serial.begin(57600);
  Serial.println("Measure voltage rev 1.0");
}

void loop() {

  if(Serial.available())
  {
    char c = Serial.read();
    if(c == 'r')
    {
      // read the value from the sensor:
      sensorValue = analogRead(sensorPin);

      Serial.print("AnalogRead: ");
      Serial.print(sensorValue);
      Serial.print("  Voltage: ");

Serial.println(((5.0*(float)sensorValue)/1024.0),
3);
    }
  }
}
```

❏ Run the program and open the Serial Monitor. Enter 'r' to read the voltage. Note that it probably won't be exactly 3.125, but it should be close.

❏ Move the jumper between resistor 1 and 2, read the voltage, then move the jumper sequentially between each resistor and read the voltage. You should have output similar to that shown in **Figure 11**.

Lab 3: Voltage Control Servo Angle

Last month, we saw how to control servo motion by sending a number over the serial port. Well, what if we want to use a servo and no PC is available. How do we set the angle then? There are, of course, many ways to do this but since we just saw how to measure nine discrete voltages using analog input, let's look at how to use those voltages to set nine discrete servo angles without having a PC. Note that the servo can vary between 0° and 180°, and that we can read nine separate voltages from 0V to 5V from our resistor ladder. Let's map the angles to the voltages, and then move the analog input jumper to different voltages to set the servo angle. Notice that this is a tricky circuit to visualize even with what's shown in **Figures 12**, **13**, and **14**.

The servomotor connector is placed on three jumper lines that are between two resistor connectors. The resistor stretches across these three lines much like a flyover highway crosses a lower road — in this case, the three empty breadboard lines under the resistor.

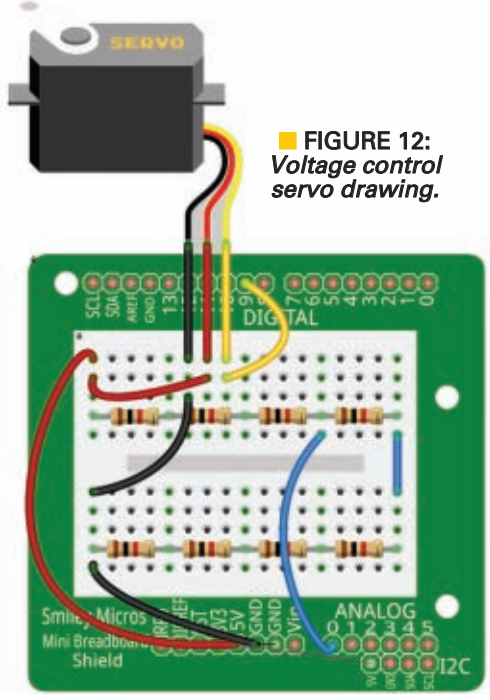


FIGURE 12: *Voltage control servo drawing.*

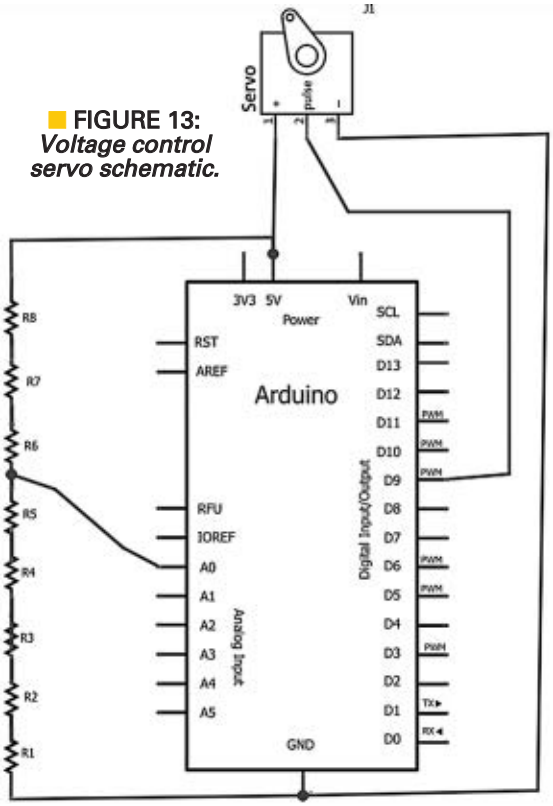


FIGURE 13: *Voltage control servo schematic.*

Parts required:
1 Arduino
1 USB cable
1 Arduino proto shield
8 1K Ω resistors
1 Servomotor and connector

Estimated time for this lab:
30 minutes

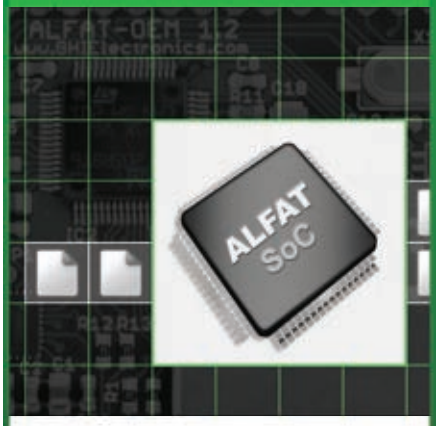
Check off when complete:

❏ Assemble the circuit shown in **Figures 12**, **13**, and **14**.

❏ Load the *A101_ch6_voltage_control_servo_angle.ino* program (at the article link) into the Arduino IDE:

```
// Voltage Control Servo Angle
// 3/31/14 Joe Pardue

#include <Servo.h>

int sensorPin = A0;  // analog input pin
int sensorValue = 0;
  // store the analog input value

Servo myservo;
  // create servo object to control a servo

int pos = 0;
  // variable to store the servo position
String readString;
```

File System Solutions



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```
void setup()
{
  // attaches the servo on pin
  // 9 to the servo
  myservo.attach(9);

  // initialize the serial
  // communication:
  Serial.begin(57600);
  Serial.flush();
  Serial.println("Voltage
control servo Angle 1.0");
}

void loop()
{
  if(Serial.available())
  {
    char c = Serial.read();
    if(c == 'r')
    {
      // read the value from
      // the sensor:
      sensorValue =
      analogRead(sensorPin);

      Serial.print
      ("AnalogRead: ");
      Serial.print
      (sensorValue);
      Serial.print
      ("  Voltage: ");
      Serial.print(  ((5.0*
      (float)sensorValue)/
       1024.0), 3);

      //float val = (float) sensorValue;
      //val = (float)map(val,0.0,1023.0,0.0,180.0);
      int val = (float)sensorValue;
      val = (float)map(val,0,1023,0.0,180);

      Serial.print("  Angle = ");
      Serial.println(val);

      myservo.write(val); // use converted angle

    }
  }
}
```

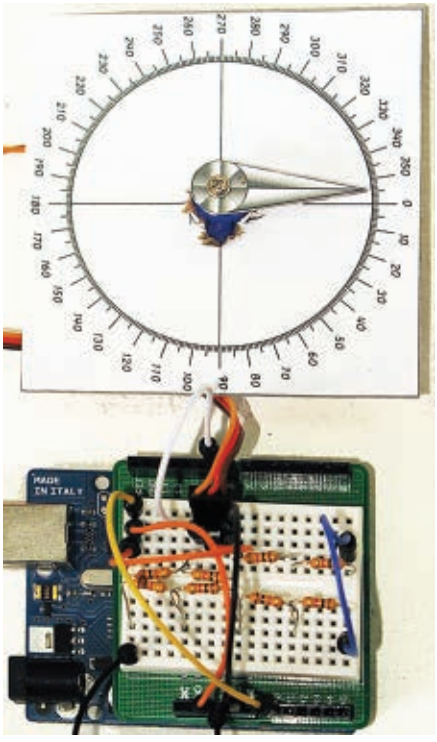

FIGURE 14: *Voltage control servo photo.*

❑ Compile and run the program.
❑ Open the Serial Monitor and sequentially move the jumper between each resistor, and send an 'r' to the Arduino between each move.
❑ Verify that you receive the text shown in **Figure 15**.

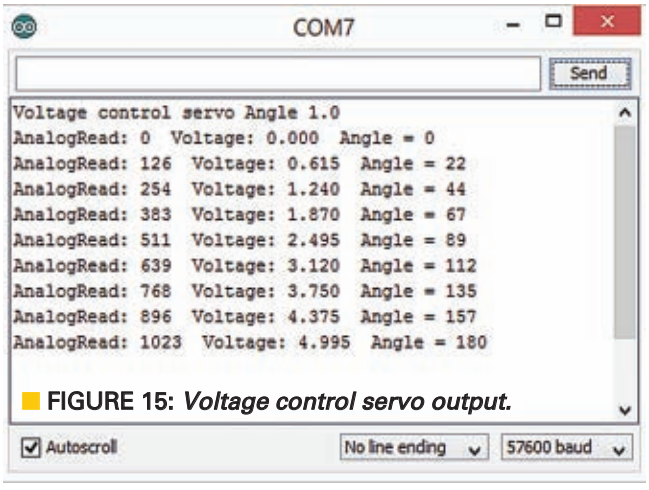

FIGURE 15: *Voltage control servo output.*

That's all for this month. Next time, we'll continue with analog output and learn about a continuously variable resistor known as a potentiometer. **NV**

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■ BY FRED EADY

The Dawn of a New EVE

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com/index.php?/magazine/article/june2014_DesignCycle**.

Graphic displays are an integral part of our lives. Sophisticated touch-enabled graphical displays are standing in for bank tellers, airline agents, and corporate human resource personnel, just to name a few.

In the old days, it took a bunch of processing power to pass information via a GUI (Graphical User Interface). In this installment of the Design Cycle, we will explore what it takes to drive a touch-enabled graphical display using a simple microcontroller.

EVE

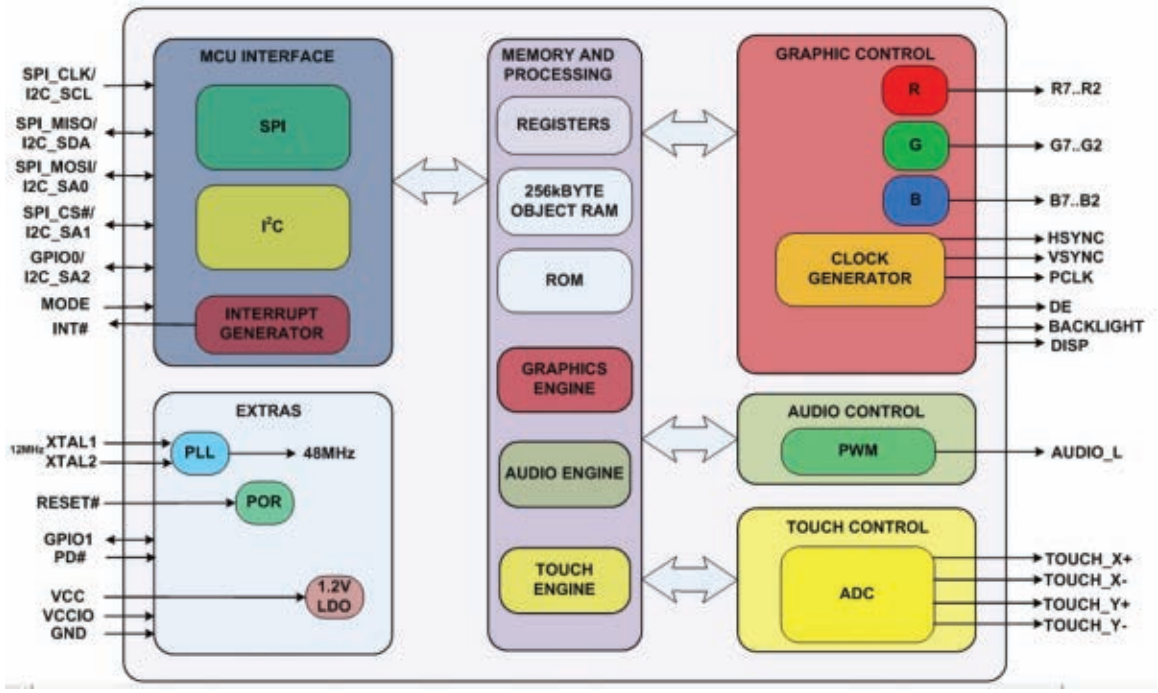
EVE is short for Embedded Video Engine. EVE represents an IC that is part of the FTDI FT800 family of video engines. EVE technology integrates display, audio, and touch into a single IC. As you might imagine, wading through the EVE technical documentation is akin to attempting to eat an elephant.

This isn't the first time we have dined on elephant during a Design Cycle discussion. From experience, we know that to consume the entire elephant we must take our time and eat it in small pieces.

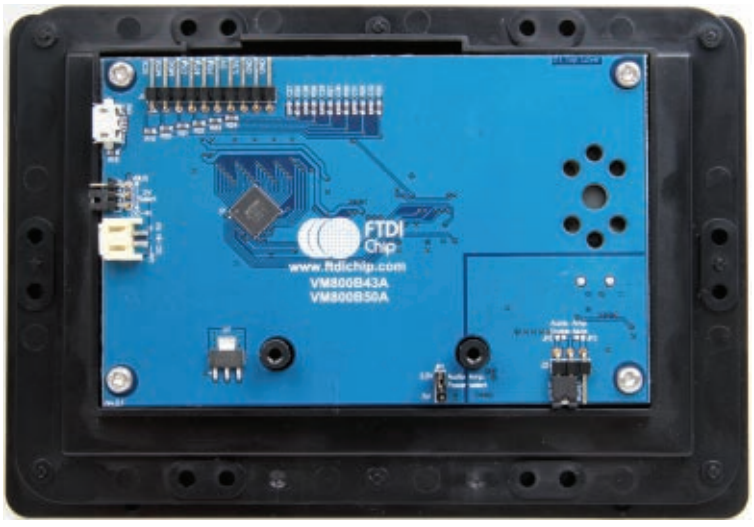
The FT800 is represented as a series of logical units in **Figure 1**.

Note that the FT800 contains all of the necessary logic to interface directly to the LCD panel. All we as users have to do is provide power, a microcontroller with an SPI or I²C microcontroller interface, a spare GPIO for the PD# (power down) input, and an external interrupt pin to support the FT800's INT# pin. To the microcontroller, an FT800 looks like a memory-mapped device attached to its SPI or I²C portal.

I have chosen to work with a prepackaged EVE solution that includes a 5.0 inch LCD panel attached to a printed circuit board (PCB) that fully supports the FT800. The FT800 development environment we will be using is readily available to



■ Figure 1. The FT800 is a very complex IC. Fortunately, the FT800's complexity is tamed by an easy-to-use object-oriented programming model. If the host microcontroller can speak SPI or I²C, it can drive the FT800.



■ Photo 1. Everything we need to succeed is in this package. In addition to the FT800, this EVE development environment includes a 3.3 volt LDO voltage regulator, level shifters for 5.0 volt tolerance on the MCU interface, an audio subsystem, a 12 MHz crystal, and a 5.0 inch touch-enabled LCD panel.

anyone, and is supplied by FTDI. As you can see in **Photo 1**, the VM800B50A EVE development unit is ready for installation, and comes complete with a bezel.

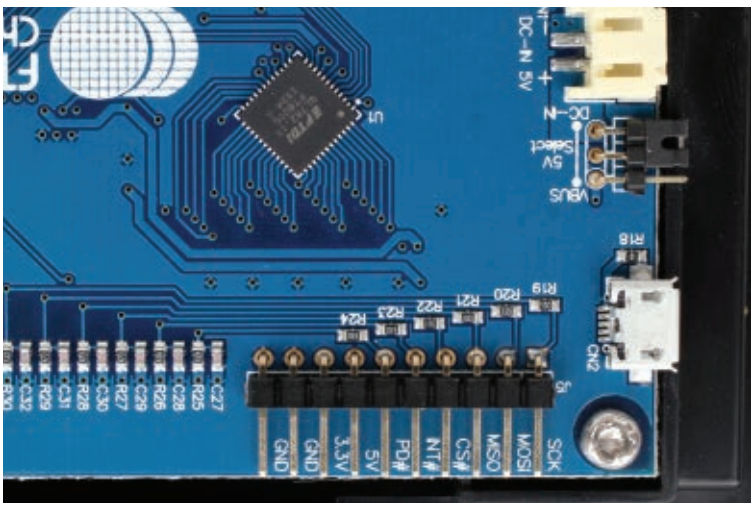
Driver Hardware

I will take you through each and every step necessary to bring our FT800 and LCD panel to life. The first order of business is to find out what the EVE unit requires as far as a hardware interface. Take a look at **Photo 2**. Note the absence of any I²C signals. That's because the development kit design ties the FT800's MODE pin to GND which enables SPI mode on the FT800's MCU interface. The USB connector does not carry any USB signals and is used to alternately supply 5.0 volt power to the EVE development environment. We will use the 10-pin male header to provide 3.3 volt power, as well as the SPI signals.

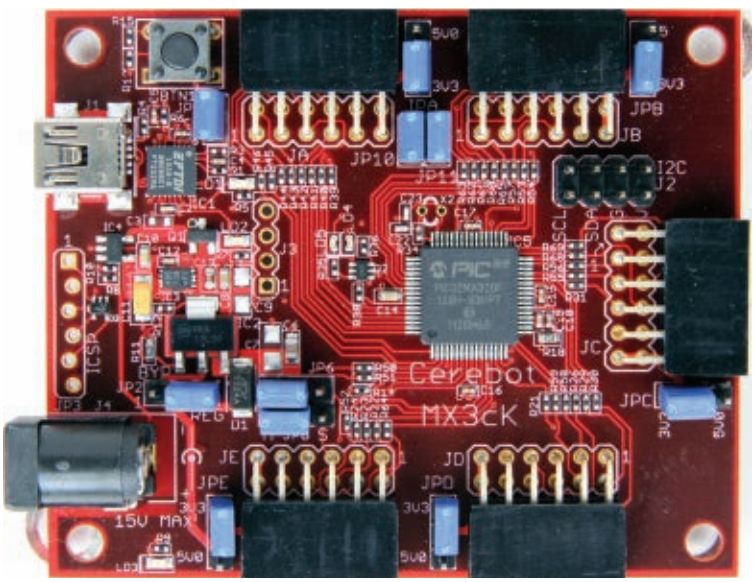
We could easily drive the FT800 with a Microchip enhanced mid-range microcontroller such as the PIC16F1829. A PIC18F microcontroller would fit nicely here, as well. This time around, we're going to change it up and use a PIC32MX device. We don't need native USB or CAN support. We also don't need large amounts of SRAM. So, we can choose a relatively "small" 32-bit PIC32MX microcontroller. Rather than reinvent the wheel, let's choose an off-the-shelf PIC32MX platform that meets our requirements.

The Digilent chipKIT MX3 shown in **Photo 3** will do nicely. The chipKIT MX3 is hosted by a PIC32MX320F128H. The chipKIT MX3's 32-bit MCU natively supports an SPI portal and a number of external interrupt pins. There are ample idle GPIO pins to service the FT800's PD# pin, as well as any other GPIO-oriented task we may have to undertake. If you wish to take a look at the entire chipKIT MX3 hardware configuration, you can download the schematic and user's manual from the Digilent site (**www.digilentinc.com**).

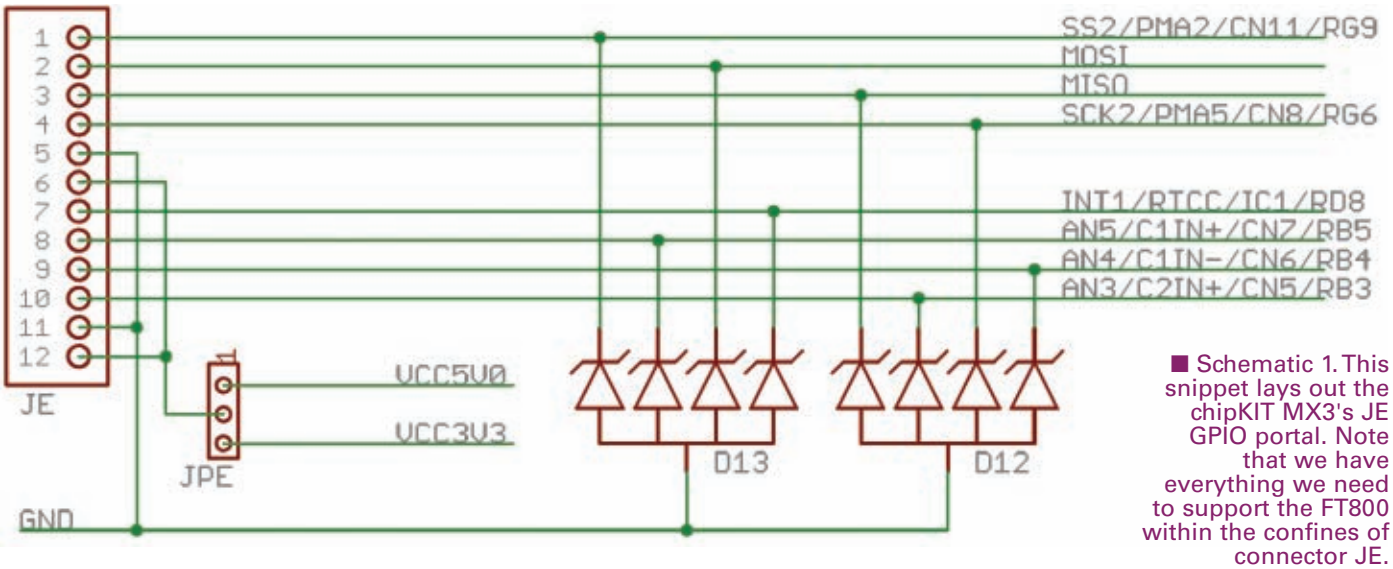
The chipKIT MX3 was originally designed to



■ Photo 2. There are no I²C interface pins as the FT800's MODE pin is tied to GND which enables SPI mode on the FT800's MCU interface.



■ Photo 3. The chipKIT MX3 was originally designed to accommodate Digilent's line of Pmods. However, the compact and logical layout of the MX3's GPIO pins makes this little board perfect for our EVE needs.



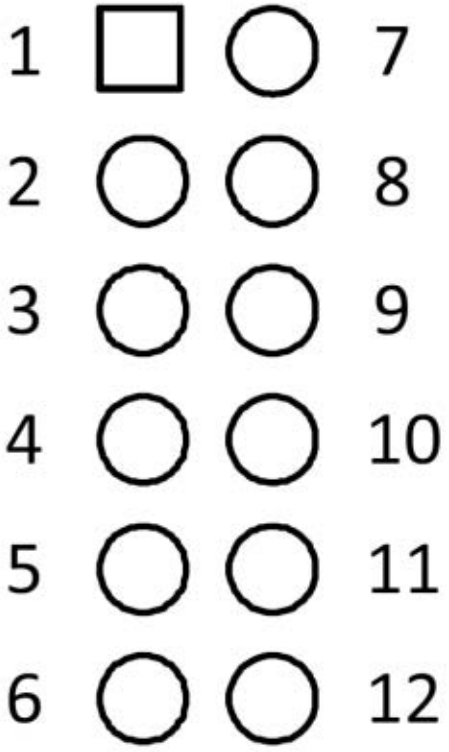
■ Schematic 1. This snippet lays out the chipKIT MX3's JE GPIO portal. Note that we have everything we need to support the FT800 within the confines of connector JE.

accommodate the line of Digilent Pmods. Thus, the chipKIT MX3's GPIO is logically divided into blocks of 12 like-minded pins. To support our EVE environment, we will need a standard four-wire SPI portal, an external interrupt pin, and a free GPIO pin to support the FT800 PD# pin.

In that we are going to employ the services of the EVE development system's 10-pin male header for both power and control, it would be nice to have our chipKIT MX3 GPIO block also provide 3.3 volt power.

If you downloaded the chipKIT MX3 schematic, you saw that the first SPI portal (SCK1, SDO1, SDI1) is multiplexed with the first UART (U1TX, U1RX). The first UART is also dedicated to the chipKIT MX3's onboard FTDI USB-to-RS-232 bridge IC. I prefer to let UART1 and SPI1 lie as-is. If we were to have a future need for a serial port, it is there for our bidding.

In addition to being designed to host Pmods, the chipKIT MX3 is also designed to be programmed using Arduino-compatible MPIDE sketches.



■ Figure 2. Normally, the odd numbered pins would be to the left and the even numbered pins would flow down on the right. We must take this layout into consideration while assembling our interface cable.

The MPIDE library assumes the exclusive use of SPI2 in MPIDE sketches. That means the chipKIT MX3 is most likely leaning towards making SPI2 easily accessible. This gut feeling about SPI2 is verified in **Schematic 1**.

The chipKIT MX3's JE connector contains the SPI2 portal signals, as well as the external interrupt signal INT1. We can use RB3, RB4, RB5, and RG9 as we please. Power for the FT800 can also be obtained from the chipKIT MX3's JE connector. We will jumper JPE for VCC3V3 3.3 volt operation. For now, let's earmark RG9 as the SPI2 CS# (Chip Select) signal and RB5 as the FT800 PD# signal.

Let's Go to Work

Now that we have decided on the host hardware platform, we must devise a tricky way to connect our chipKIT MX3's SPI portal to the FT800's MCU interface. After much thought, it came to me that the chipKIT MX3 has standard Digilent connectors.

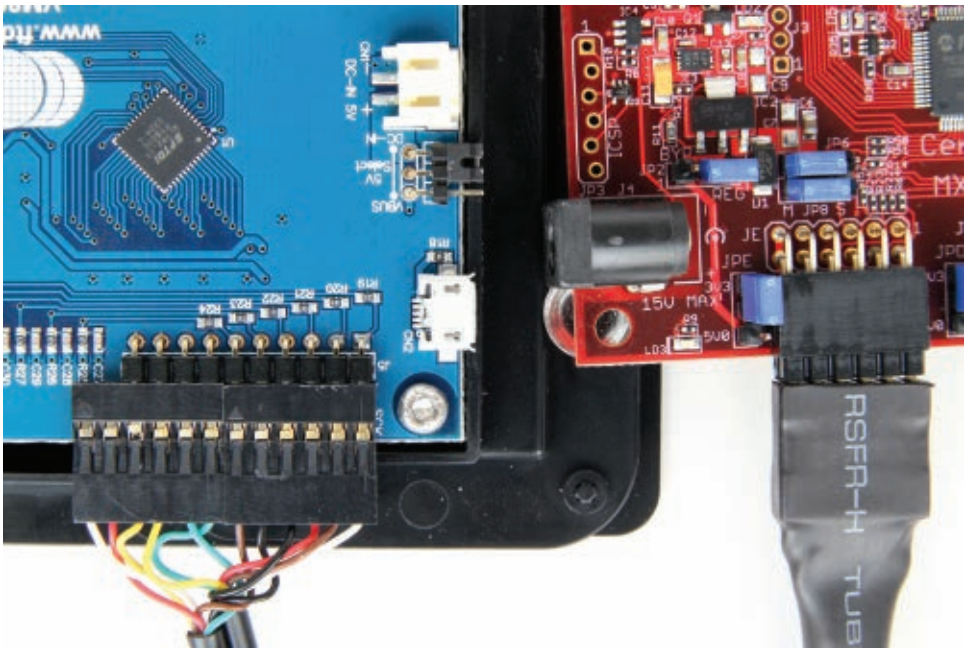
What I mean by "standard" is that each chipKIT MX3 connector has power on pins 6 and 12, and GND on pins 5 and 11. The layout of the SPI signals matches that of the associated SPI-driven Pmod. So, all we have to do is build up a custom cable that will make the FT800 look like an SPI-driven Pmod.

The first gotcha is the chipKIT MX3 connector layout

you see in **Figure 2**. Instead of columns of odd numbered and even numbered pins, the Digilent Pmod standard uses the pattern shown in **Figure 2**. We must keep this Digilent layout in mind as we assemble our SPI portal interface cable.

Digilent supplies a six inch cable (Part# 250-030) that splits out the 12-pin female header layout you see in **Figure 2** to a pair of six-pin female headers. The female headers on both sides of the cable are tightly wrapped with heat shrink tubing.

There is no reason to remove the heat shrink on the 12-pin side as we will use it as a reference. Removing the heat shrink tubing on the six-pin side reveals plastic housings that can be manipulated to allow the nondestructive removal of the six female header pins.

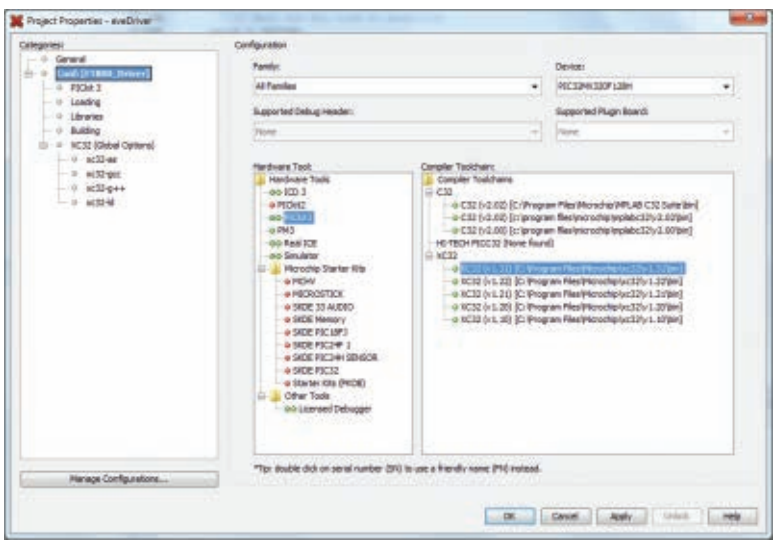


■ Photo 4. A neat and easy way to make a custom cable based on off-the-shelf Digilent components.

All we have to do is remove and replace the pins on the six-pin side of the cable to match the pinout demanded by the EVE 10-pin male header. Digilent also provides elongated male header pins (part# 240-004) that act as a gender changer, so the 12-pin side of the cable can be connected to the chipKIT MX3 12-pin female connector.

Note that there are no 5V0 connections at connector JE on the chipKIT MX3 side. In reality, there are no 5V0 connections on the EVE side either. We are, in reality, connecting the second 3V3 pin on the JE connector to the 5V0 pin on the EVE header. This bypasses the 3.3 volt voltage regulator that is part of the EVE development system.

Alternately, we could jumper JPE to output five volts at JE pins 6 and 12. This would allow us to feed five volts to the EVE 5V0 pin which is the input of the onboard 3.3 volt regulator. I try not to mix 3.3 and 5.0 volt rails without reason. The elimination of the five volt power signal keeps things simple. The customized cable is shown doing its thing in **Photo 4**.



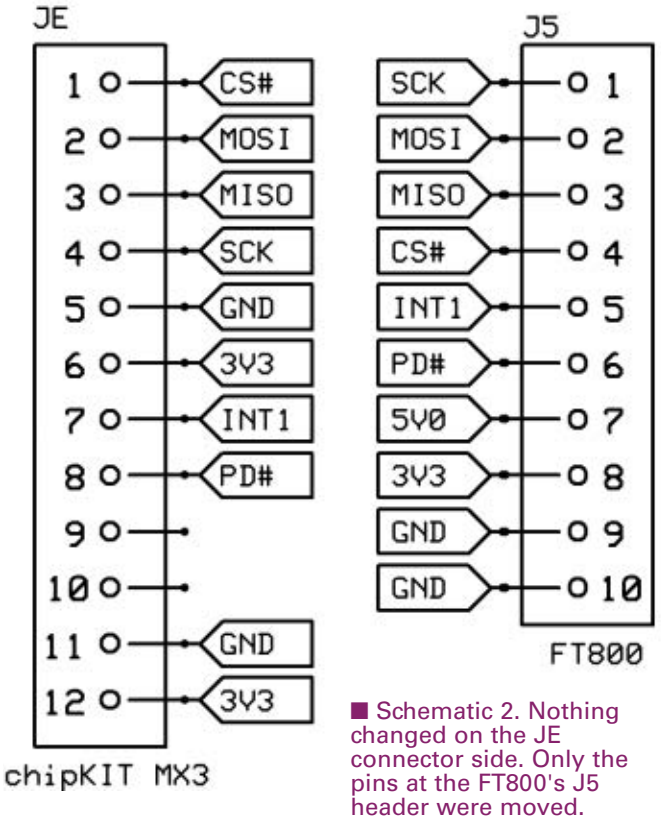
■ Screenshot 1. The more you use MPLAB X, the more you will grow to like it. As you can see here, I've created a configuration called *FT800_Driver* that uses the latest version of XC32 to build code for a PIC32MX320F128H. The programmer/debugger of choice is a PICkit 3.

The X Factor

Although the chipKIT MX3 was intended as an MPIDE hardware component, the chipKIT MX3 can also be programmed in the traditional way. So, we will build the FT800 driver using MPLAB X, XC32, and a PICkit 3.

This is validated in **Screenshot 1**. Now that our MPLAB X project is set up, let's walk through putting the firmware framework together.

It is of utmost importance to establish MCU clock speeds. The chipKIT MX3's PIC32MX320F128H is capable of running at 80 MHz. Let's make that happen:



■ Schematic 2. Nothing changed on the JE connector side. Only the pins at the FT800's J5 header were moved.

```
//************************************************
//* CONFIGURATION BITS
//************************************************
    #pragma config FPLLMUL          = MUL_20
      // PLL Multiplier
    #pragma config FPLLIDIV         = DIV_2
      // PLL Input Divider
    #pragma config FPLLODIV         = DIV_1
      // PLL Output Divider
    #pragma config FPBDIV           = DIV_1
      // Peripheral Clock divisor
    #pragma config FWDTEN           = OFF
      // Watchdog Timer
    #pragma config WDTPS            = PS1
      // Watchdog Timer Postscale
    #pragma config FCKSM            = CSDCMD
      // Clk Switching & Fail Safe Clock
      // Monitor
    #pragma config OSCIOFNC         = OFF
      // CLKO Enable
    #pragma config POSCMOD          = HS
      // Primary Oscillator
    #pragma config IESO             = OFF
      // Internal/External Switch-over
    #pragma config FSOSCEN          = OFF
      // Secondary Oscillator Enable
    #pragma config FNOSC            = PRIPLL
      // Oscillator Selection
    #pragma config CP               = OFF
      // Code Protect
    #pragma config BWP              = OFF
      // Boot Flash Write Protect
    #pragma config PWP              = OFF
      // Program Flash Write Protect
    #pragma config ICESEL           = ICS_PGx2
      // ICE/ICD Comm Channel Select
```

The chipKIT MX3's PIC is clocked using an 8 MHz crystal reference. Using the PIC32MX's PLL, we multiply the crystal reference by 20 and divide the result by two to arrive at our 80 MHz MCU clock frequency. The MCU peripheral clock is also moving along at 80 MHz. The watchdog timer is disabled, as well as any code protection.

One of the reasons I chose to go with a PIC32MX part is the excellent library support. The inclusion of the peripheral library allows a great deal of abstraction at the register and register bit levels. The *plibs* come in handy when manipulating peripherals like the SPI portals and UARTs:

```
//************************************************
//* INCLUDES
//************************************************
#include <xc.h>
#include <plib.h>
#include <stdlib.h>
#include <string.h>
#include <stdio.h>
#include "GenericTypeDefs.h"
```

Many peripherals such as the SPI portals and UARTs need to know about the clock speeds. Knowledge of clock speeds allows the peripherals to be set up to run at those desired bit speeds. For instance, the FT800 wants to see a SPI data stream running at 10 MHz or below at startup. Once the FT800 is initialized, the SPI speed can be increased three-fold.

Another very good reason I went with a 32-bit PIC revolves around the ability to *SET*, *CLEAR*, and *INVERT* bits within certain registers atomically. That's a fancy way of saying that it only takes one instruction cycle. We will use the atomic bit manipulation feature whenever and wherever we can. Here is how we will drive the SPI CS# signal and the FT800 PD# signal using atomic operations:

```
//************************************************
// I/O PIN ALIASES
//************************************************
#define CSlo                LATGCLR = 0x0200;
   //0000 0010 0000 0000
#define CShi                LATGSET = 0x0200;

#define PDlo                LATBCLR = 0x0020;
   //0000 0000 0010 0000
#define PDhi                LATBSET = 0x0020;
//************************************************
// chipKit MX3 LEDs
//************************************************
#define LD4on               LATFSET = 0x0001;
    //0000 0000 0000 0001
#define LD4off              LATFCLR = 0x0001;
#define LD4tog              LATFINV = 0x0001;
#define LD5on               LATFSET = 0x0002;
    //0000 0000 0000 0010
#define LD5off              LATFCLR = 0x0002;
```

Taking a look back at **Schematics 1** and **2**, you will recall that we chose to assign the chipKIT MX3's CS# functionality to GPIO pin RG9. To drive CS# logically low, we run the *LATGCLR* operation against the ninth bit of

PORTG. Conversely, to take the CS# signal logically high, the *LATGSET* operation is applied against the same PORTG bit. The chipKIT MX3's user LEDs are driven by NPN transistors. So, the logic will be reversed. To illuminate an LED, you turn the transistor on by setting the attached GPIO pin (*LATFSET*). We can use the *INVERT* atomic operation to toggle a chipKIT MX3 user LED (*LATFINV*). The atomic bit operations also work well with the *TRISx* registers:

```
TRISBCLR = 0x0020; //0000 0000 0010 0000
TRISGCLR = 0x0200; //0000 0010 0000 0000
TRISFCLR = 0x0003; //0000 0000 0000 0011
```

The *TRISBCLR* operation makes RB5 (PD#) an output pin. Recall that RG9 has been assigned to *chip select* duty. We set RG9 as an output pin with the *TRISGCLR* operation.

The user LED GPIO pins are last to be set up with a *TRISFCLR* operation, forcing RF0 and RF1 output pins to output mode.

The chipKIT MX3 initialization code also performs other important MCU setup tasks. One of the more common mistakes that causes days of head-scratching is the failure to disable the analog inputs before setting them up as digital I/O. To avoid this headache, we'll kill all of the PIC32MX320F128H analog inputs and force them to the digital mode. This is done by writing to the *AD1PCFG* register:

```
AD1PCFG = 0xFFFF;
```

Earlier, we performed some frequency setup using the configuration fuse bits. The PIC32MX320F128H does its best work when we pay attention to details when it comes to the PIC's *PLL* and *CPU* cache:

```
value = SYSTEMConfigWaitStatesAndPB
  ( GetSystemClock() );
// Enable the cache for the best performance
CheKseg0CacheOn();
// Wait for PLL lock to stabilize
value = OSCCON;
while (!(value & 0x00000020))
{
    value = OSCCON;
}
```

RESOURCES

Microchip
XC32
MPLAB X
PICkit 3
www.microchip.com

FTDI
FT800
VM800B50A
www.ftdichip.com

Digilent, Inc.
chipKit MX3
www.digilentinc.com

Another gotcha that is peculiar to 32-bit PICs is the failure to disable the JTAG pins. The JTAG pins share space with some of the GPIO pins, and block the base GPIO functionality of the shared GPIO pin. Again, a single wave of the sword takes care of any JTAG interference:

```
DDPCONbits.JTAGEN = 0;
```

It's a given that we will be using the PIC's SPI2 portal. We need to set it up before we attempt to use it:

```
SPI2CONbits.ON       = 0;
       //disable SPI2 peripheral
SPI2CONbits.MSTEN    = 1;
       //Master mode
SPI2CONbits.CKP      = 0;
       //polarity idle low
SPI2CONbits.CKE      = 1;
       //transmit on active to idle
SPI2CONbits.SMP      = 0;
       //sample in the middle
SPI2BRG              = 0x03;
       //10MHz SPI clock
SPI2CONbits.ON       = 1;
       //enable SPI2 peripheral
```

The SPI2 settings match other code that I have used to communicate with devices in mode 0. So, it should fly the first time as only the names of the registers have changed here.

While we're throwing out proven code, let's go ahead and lay down our basic SPI function:

```
void sendspi(unsigned char bite)
{
  CSlo;
  scratch8 = SPI2BUF;
       //clear BF
  SPI2BUF = bite;
       //write byte to SSPBUF register
  while(!SPI2STATbits.SPIBUSY);
       //wait until bus cycle complete
  CShi;
}
```

Back to the Books

We've got more work to do before we can produce any pixels. We have an external interrupt handler routine to write. There are also a few base commands that need to be crafted. The FT800 wants to see everything in Little Endian format. That means we must write some routines to convert our commands and data.

Once we get the FT800 on its feet, there is yet more display code we will need to write. I don't know about you, but I can't eat another byte of elephant right now. So, I think I'll pull out my FT800 *Programmer's Guide* and grab a glass of iced tea. Next month, we'll go a bit deeper into our FT800 driver project. **NV**

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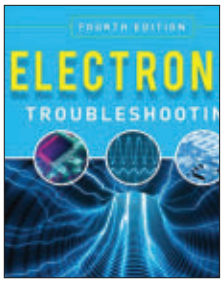

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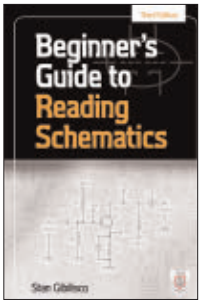
by Stan Gibilisco



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Build Your Own Transistor Radios
by Ronald Quan

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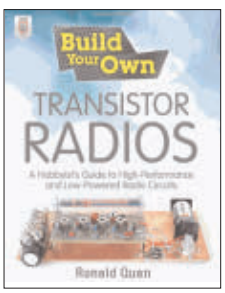

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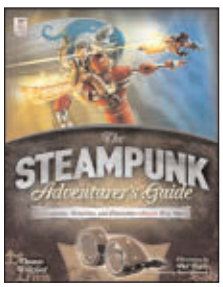
The Steampunk Adventurer's Guide
by Thomas Willeford



Steampunk stalwart Thomas Willeford cordially invites you on an adventure — one in which you get to build ingenious devices of your own! Lavishly illustrated by award-winning cartoonist Phil Foglio, *The Steampunk Adventurer's Guide: Contraptions, Creations, and Curiosities Anyone Can Make* presents 10 intriguing projects ideal for makers of all ages and skill levels, woven into an epic tale of mystery and pursuit.

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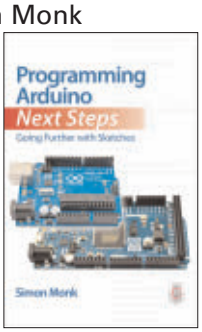
Programming PICs in Basic
by Chuck Hellebuyck

If you wanted to learn how to program microcontrollers, then you've found the right book! Microchip PIC microcontrollers are being designed into electronics throughout the world and none is more popular than the eight-pin version. Now the home hobbyist can create projects with these little microcontrollers using a low cost development tool called the CHIPAXE system and the Basic software language. Chuck Hellebuyck introduces how to use this development setup to build useful projects with an eight-pin PIC12F683 microcontroller. **$14.95**

Programming Arduino Next Steps: Going Further with Sketches
by Simon Monk



In this practical guide, electronics guru Simon Monk takes you under the hood of Arduino and reveals professional programming secrets. Also shows you how to use interrupts, manage memory, program for the Internet, maximize serial communications, perform digital signal processing, and much more. All of the 75+ example sketches featured in the book are available for download. **$20.00**

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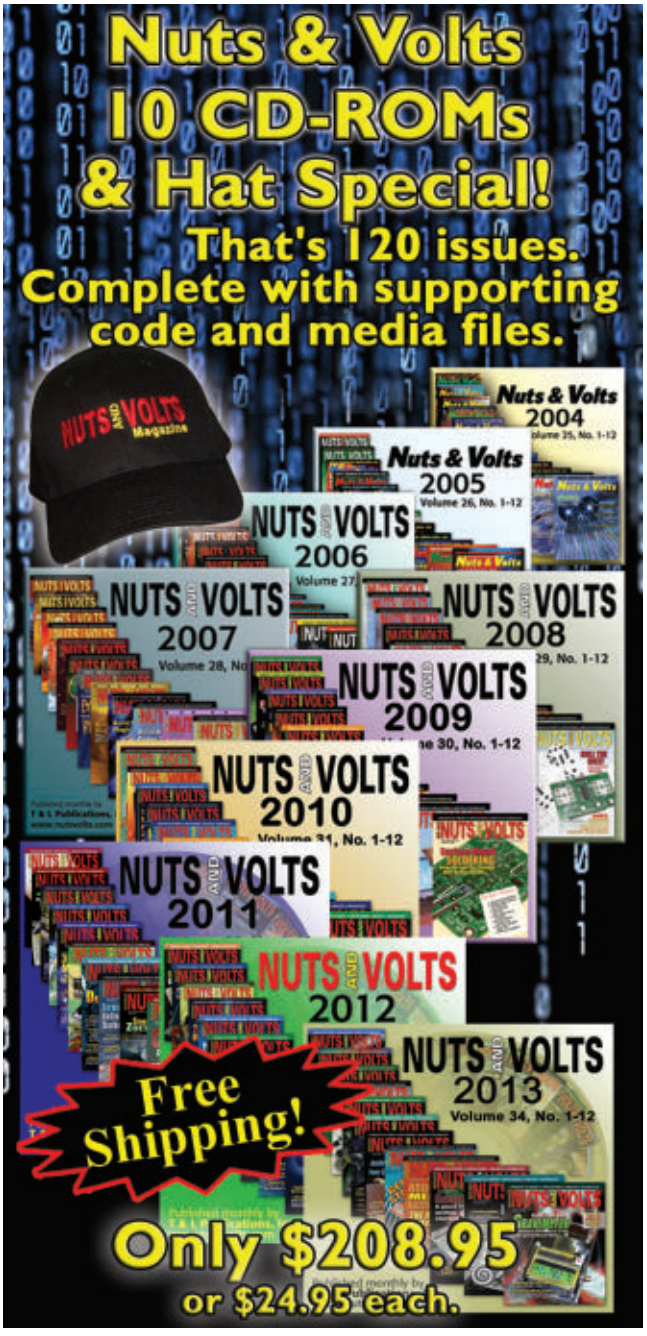

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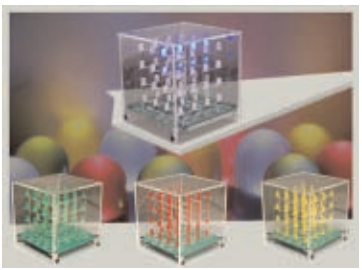

This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes.
Colors available: Green, Red, Yellow & Blue

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Geiger Counter Kit

As seen in the March 2013 issue.
This kit is a great project for high school and university students. The unit detects and displays levels of radiation, and can detect and display dosage levels as low as one micro-roentgen/hr. The LND712 tube in our kit is capable of measuring alpha, beta, and gamma particles.

Partial kits also available.

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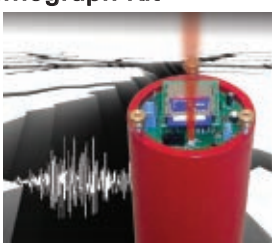

As seen in the May 2012 issue.
Now you can record your own shaking, rattling, and rolling.
The Poor Man's Seismograph is a great project /device to record any movement in an area where you normally shouldn't have any. The kit includes everything needed to build the seismograph. All you need is your PC, SD card, and to download the free software to view the seismic event graph.

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As seen in the November 2011 issue.
Battery Marvel helps protect cars, trucks, motorcycles, boats, and any other 12V vehicles from sudden battery failure. This assembled unit features a single LED that glows green, yellow, or red, indicating battery health at a glance. An extra-loud piezo driver alerts you to any problems.
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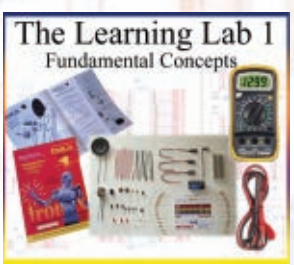

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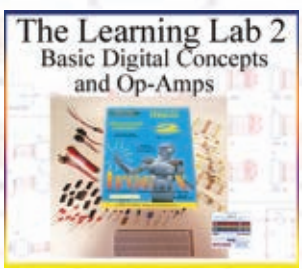

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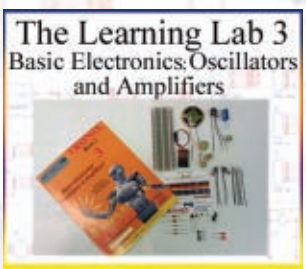

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FM Instead of Wi-Fi

I would like to use a device such as a Pi or Arduino to connect to an Ethernet. I want to send/receive data wirelessly via digital FM instead of Wi-Fi to communicate with devices where the Wi-Fi/internet connection is unavailable, but still relatively close (suitable for low power FM where FCC regulations would not be an issue).

High speed data transfer such as for streaming video is not a must, but 100-200 kps would be ideal. This would, of course, vary depending on the strength of my signal.

Can I buy a board with Ethernet and simply I/O data to an FM transceiver? Any suggestions to help me get started would be great.

#6141 **Gary McPherson**
Wyoming, MI

Delay Circuit Needed

I need a little help with an automatic above ground pool filler circuit I constructed. It's nothing complicated – a water level switch with a power supply. When the water level drops below the set point of the float switch, it completes the circuit which applies 12 VDC to a solenoid which activates and allows the water to flow.

When the water level comes up and the float switch raises up to the preset point, the reverse happens and the water stops flowing.

My problem is I need some sort of delay before the power supply sends 12 VDC to the water relay. The float switch – due to motion by the wind or vibration – normally keeps the water level switch bouncing. This, in turn, keeps the water constantly turning on and off. If there was a 15 to 30 second delay until the float switch stabilized in one condition – either on or off – it would prevent the water switch from constantly going on and off.

Anyone out there with a circuit that can do this? It would be even better if the same timer also supplied the voltage for the water relay. Thanks in advance.

#6142 **Gary Lichtenstein**
Las Vegas, NV

Battery Charging Indicator

My truck only has a voltmeter for battery condition indication. I don't have room for an ammeter. Is there a circuit I could build with a red and green LED to indicate if the battery is charging or discharging?

#6143 **Ray**
via email

Call Blocker

Telemarketing has gotten both ultra sophisticated and out of control. Do Not Call listings are a waste.

I'd like to stop all incoming calls short at the point of entry, unless the caller – on receiving a prompt – dials an additional pass code to access my stand-alone answering machine and simultaneously ring any phones on which the ringer is turned on.

Is a DIY circuit available? Is anything off-the-shelf available? I checked with AT&T marketing and all they offer is blocking of all calls where no telephone number or caller name is available. That's not what I want.

#6144 **Robert Wheaton**
San Antonio, TX

Renewing Permanent Magnets

I have an old style hand crank telephone generator. It works, but output voltage is low due to the four horseshoe magnets it uses being weak. What is the best way to revitalize these magnets to bring the generator back to like-new operating condition?

Also, how can I tell when – as a result of the revitalization process – the magnets have achieved maximum strength and won't get any stronger?

#6145 **David LeFevre**
Ontario, NY

>>> ANSWERS

[#3143 - March 2014]

Sweep Generator Range

I have a Heathkit sweep generator 1274 which I bought with the hope I could quickly determine the frequency response of amplifiers I play with from time to time. However, there is no way to determine the range of the pattern on my scope – at least none that I have figured out. I'm not very advanced in such matters. Is there any easy way to add blips to the pattern say at 12 kHz and or 15 kHz?

One way to do this is to connect a series L-C tuned circuit (high Q) across the input of the amp under test. Since capacitors are higher Q than inductors, a high value cap and low value inductor would be best. I chose a 470 uH inductor (Mouser 580-22R474C, $0.59) and 0.374 µF capacitor for a 12 kHz notch.

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Always use common sense and good judgment!

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If you use the internal attenuator of the IG-1274 to set the level, the notch circuit has to work against the 50 ohm output impedance. However, if you use an external attenuator, a lower output impedance and sharper notch can be obtained. In any case, you probably don't want the notch in the circuit all the time, so a pushbutton switch would let you see where the frequency is without distorting the response.

Russell Kincaid
Milford, NH

[#4142 - April 2014]
Arduino Power Requirements

I'm using an external 6V supply to power an Arduino circuit which is giving me problems. I heard somewhere that the Arduino requires at least 7 or 8 VDC input. Doesn't the Arduino run on 5V? Can someone clarify?

According to the Arduino specifications at **http://arduino.cc/en/Main/ArduinoBoardUno**, "The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts." So you must either provide five volts through the USB port from a PC or a USB hub, or a minimum of seven volts through the power jack from the external power input. I recommend a nine volt, 500 milliamp wall wart.

Raymond J. Ramirez
via email

[#5142 - May 2014]
Thermocouple Switcher

I want to read and log temperatures from multiple points in my central heating system. I want to use thermocouples because: ***1)*** *They are easy to attach to my hot water cylinder (stabbed under the insulation); and* ***2)*** *I already have them — from IKEA, meat thermometers.*

I would like to select each thermocouple in turn, use a single amplifier/analog-to-digital stage (Max31855 ??) to obtain the reading, and move on to the next one.

I need ideas for switching between the different thermocouples without introducing unwanted switch resistances, etc. Would an array of reed switches driven by a shift register be a sensible solution? Is there a better solid-state solution?

First, people have a misconception that the junction of dissimilar materials form a thermocouple. Actually, the junction creates a return path for current that flows due to the Seebeck effect, discovered in 1822. In essence, a temperature difference between the ends of a conductor creates a small EMF — or voltage — between the ends. A type-E thermocouple (constantan and chromel wires) has a 68 µV/°C coefficient which means you'll see a 680 µV increase for a 10°C increase in temperature between the ends of the thermocouple wires. Of course, you need to know the temperature at the switches you use in your measurement systems. People often refer to this as cold-junction compensation, and many diagrams show an ice bath at 0°C. You just need an accurate temp sensor, not an ice bath.

Second, I recommend reed relays; either two SPST or one DPST relay will do the job nicely. Some people might say, "Wait, all the connections to the relays create individual thermocouples." Not so, the difference in voltage between the ends of the relay conductors and associated conductors amounts to a negligible amount. Just keep your equipment at a fairly stable temperature. Depending on the ADC you use, you might need an accurate instrumentation amplifier between the thermocouple signal from the relays to the ADC. Again, the measured voltage results from the temperature difference between the end of the thermocouple and the temperature measured at the thermocouple wire ends in your measurement system.

For more information, I recommend the free ebooks, *Switching Handbook* and *Low Level Measurements Handbook*, from Keithley Instruments at **www.keithley.com/knowledgecenter**. Also, see the article at **ttp://tinyurl.com/kuvd93o**.

Jon Titus
Herriman, UT

[#4143 - April 2014]
How Much Heat Can a Battery Take?

I need to shrink wrap sets of AA lithium batteries for a radio project. Can I safely heat the shrink wrap with a hot air blower without harming or causing the batteries to explode?

Absolutely. Heat shrink covering has a very low thermal mass — much lower than the batteries. You can hit it with a heat gun and it will shrink up tight long before the batteries get more than warm to the touch. As long as you don't keep cooking them for an extended period of time, it will be fine.

James Sweet
via email

[#4146 - April 2014]
Laser Power Supply

eBay had an amazing deal on high power IR lasers. I want to build a laser cutting tool with one of the laser diodes. The heatsink isn't a problem, but I'm having trouble designing a constant current power supply that can handle the 50W laser. Commercial supplies are hundreds of dollars.

Try the circuit used at **www.die4laser.com/dvd-rec/Die4Drive.htm** as a starting point. Obviously, you will need to size the MOSFET and heatsink appropriately as well as the current sense resistor for the power

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or via the online form at **www.nutsvolts.com/tech-forum**

involved, but it should get you going in the right direction. A standard ATX computer power supply can often be repurposed as a high current DC source to power the thing.

James Sweet
via email

[#5145 - May 2014]
Pot Cleaning

I recently purchased a small "pignose" guitar amplifier at a garage sale. I put batteries in it and it works, but the volume knob is very "scratchy" and at certain places in its rotation, the sound cuts out entirely. Is this something I could fix by cleaning the potentiometer and if so, what would I use? If it's time for a replacement, does anyone know where I could find a schematic?

The best fix is to replace the pot. If you don't want to do that, then a spray-on cleaner is available at most RadioShack or electronic parts supplies that will supposedly clean these pots. I've never had much success with the spray stuff though. It's supposed to wash away the carbon dust and leave a protective slippery film behind to prevent further wear. My preferred method is to disassemble the pot, clean it thoroughly with alcohol, re-lube it with pot grease, then reassemble it. Even all this doesn't permanently fix the problem; it will return.

The problem is usually caused by the carbon resistance material breaking down. Most pots have their value stamped somewhere on the case; generic replacements are available and are cheap and easy to install.

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Super-Pro FM Stereo Radio Station

- ✔ **PLL synthesized for drift-free operation**
- ✔ **Built-in mixer - 2 line inputs and one microphone input, line level monitor output!**
- ✔ **Frequency range 88.0 to 108.0, 100 kHz steps**
- ✔ **Precision active low-pass "brick wall" audio filter!**
- ✔ **Dual LED bar graph audio level meters!**
- ✔ **Automatic adjustable microphone ducking!**
- ✔ **Easy to build through-hole design!**

This professional synthesized transmitter is adjustable directly from the front panel with a large LED digital readout of the operating frequency. Just enter the setup mode and set your frequency. Once selected and locked you are assured of a rock stable carrier with zero drift. The power output is continuously adjustable throughout the power range of the model selected. In addition, a new layer of anti-static protection for the final RF amplifier stage and audio inputs has been added to protect you from sudden static and power surges.

Audio quality is equally impressive. A precision active low-pass brick wall audio filter and peak level limiters give your signal maximum "punch" while preventing overmodulation. Two sets of rear panel stereo line level inputs are provided with front panel level control for both. Standard unbalanced "RCA" line inputs are used to make it simple to connect to the audio output of your computer, MP3 player, DVD player, cassette deck or any other consumer audio source. Get even more creative and use our K8094 below for digital storage and playback of short announcements and ID's! In addition to the line level inputs, there is a separate front panel microphone input. All three inputs have independent level controls eliminating the need for a separate audio mixer! Just pot-up the source control when ready, and cross fade to the 2nd line input or mic! It's that simple! In addition to the dual stereo line inputs, a stereo monitor output is provided. This is perfect to drive studio monitors or local in-house PA systems.

The FM100B series includes an attractive metal case, whip antenna and built in 110/220VAC power supply. A BNC connector is also provided for an external antenna. Check out our Tru-Match FM antenna kit, for the perfect mate to the FM100B transmitter.

We also offer a high power kit as well as an export-only assembled version that provides a variable RF output power up to 1 watt. The 1 watt unit must utilize an external antenna properly matched to the operating frequency to maintain a proper VSWR to protect the transmitter. *(Note: The FM100B and FM100BEX are do-it-yourself learning kits that you assemble. The end user is responsible for complying with all FCC rules & regulations within the US or any regulations of their respective governing body. The FM100BWT is for export use and can only be shipped to locations outside the continental US, valid APO/FPO addresses or valid customs brokers for documented end delivery outside the continental US).*

FM100B	**Super-Pro FM Stereo Radio Station Kit, 5uW to 25mW Output**	**$269.95**
FM100BEX	**Super-Pro FM Stereo Radio Station Kit, 5uW to 1W Output**	**$349.95**

Audio Recorder & Player

Record and playback up to 8 minutes of messages from this little board! Built-in condenser mic plus line input, line & speaker outputs. Adjustable sample rate for recording quality. 4-switch operation that can be remote controlled! Runs on 9-12VDC at 500mA.

K8094 **Audio Recorder/Player Kit** **$32.95**

Water Sensor Alarm

This little $7 kit really shined during Sandy! Simply mount the alarm where you want to detect water level problems. When the water level rises it touches the contacts and the alarm goes off! Sensor can even be remotely located. Runs on a 9V battery (not included).

MK108 **Water Sensor Alarm Kit** **$6.95**

12VDC Regulated

Go green with our new 12VDC 1A regulated supply. Worldwide input 100-240VAC with a Level-V efficiency! It gets even better, includes DUAL ferrite cores

AC121 **12VDC 1A Regulated Supply** **$9.95**

12VDC Worldwide

It gets even better than our AC121 to the left! Now, take the regulated Level-V green supply, bump the current up to 1.25A, and include multiple blades for global country compatibility!

PS29 **12VDC 1.25A Global Supply** **$19.95**

Passive Aircraft Monitor

PATENTED!

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 **Passive Aircraft Receiver Kit** **$89.95**

Signal Magnet Antenna

The impossible AM radio antenna that pulls in the stations and removes the noise, interference, and static crashes from your radio! Also helps that pesky HD AM Radio stay locked! Also available factory assembled.

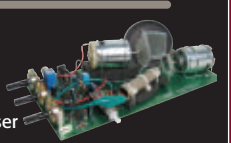
SM100 **Signal Magnet Antenna Kit** **$89.95**

Laser Trip Sensor Alarm

True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 **Laser Trip Sensor Alarm Kit** **$29.95**

Laser Light Show



Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 **Laser Light Show Kit** **$49.95**

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PL130A Gives you 130 different electronic projects together with a comprehensive learning manual describing the theory behind all the projects.

PL200 Includes 200 very creative fun projects and includes a neat interactive front panel with 2 controls, speaker, LED display and a meter.

PL300 Jump up to 300 separate projects that start walking you through the learning phase of digital electronics.

PL500 The ultimate electronics lab that includes 500 separate projects that cover it all, from the basics all the way to digital programming.

SP1A Whether young or old, there's always a need to hone your soldering skills. Either learn from scratch or consider it a refresher, and end up with a neat little project when you're done!

SM200K Move up to Surface Mount Technology (SMT) soldering, and learn exactly how to solder those tiny little components to a board!

AMFM108K We not only take you through AM and FM radio theory but we guide you through IC's. When you're done you've built yourself an IC based AM/FM radio that works great!

AM2 Learn the complete theory of AM broadcast radio and end up with a highly sensitive AM radio receiver!

AMFM7 Step up to AM/FM with this multi-band lab and learn the basics of both bands. The FM tuner is factory assembled and aligned!

SR3 Enter the world of SWL with this shortwave radio learning lab covering 6-8MHz and 12-18MHz!

AK870 One of the most exciting electronic learning kits that the kids will love! Build a complete RC speedster from the ground up! 7 remote functions!

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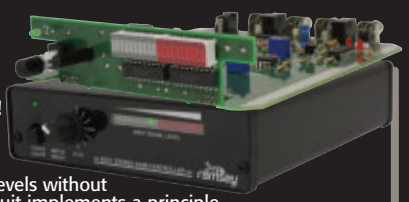
Stereo Audio Platform Gain Controller



- ✔ **Stereo audio processing while preserving audio dynamics!**
- ✔ **True stereo control keeps virtual sonic source location intact!**
- ✔ **Auto-bypass restores original levels when power is turned off!**
- ✔ **Built-in bar graph indication of signal level with display mute!**

The SGC1 is one of our latest kits, and provides a great solution to the age-old problem: how can we easily correct inconsistent audio levels without negatively affecting the dynamics of the audio signal? The SGC1 circuit implements a principle known as the "Platform Gain Principle," which was originally developed by CBS Labs to allow transmitted audio levels to be automatically adjusted to keep them within a desired range.

Think of it like an audio engineer, constantly adjusting the output level in order to limit highs that would be too loud while boosting lower levels so that they can still be heard. You may think "oh, this is just another limiter/compressor!" Not so! Here's the real trick: keeping the full dynamic range ratio of the output signal the same as the original input - something the typical limiter/compressor can only dream of doing! The SGC1 can be placed in just about any standard analog stereo line level audio circuit to keep the audio level within the desired range. It's also the perfect addition to any of our hobby kit transmitters, allowing you to match levels between different audio sources while keeping lows audible and preventing the highs from overdriving.

In addition to its useful basic function and great audio performance, the SGC1 also boasts a front panel LED meter to give an indication of the relative level of the input signal, as well as a front level control that allows you to adjust the controller to the min/max center point of your desired level range. And yes, it is a ***Stereo Gain Controller!*** Meaning that the levels of both the left and right channels are monitored and adjusted equally, thereby maintaining the relative virtual position of things like instruments, singers and speakers! The entire unit is housed in a slim attractive black textured aluminum case that is sure to complement your studio or home theatre. If you're looking for perfect audio levels, hire a broadcast audio engineer, but if that doesn't fit your budget, the SGC1 is the next best thing! Includes 15VDC world-wide power adapter.

SGC1 **Stereo Audio Platform Gain Controller Kit** **$179.95**

IN-8-2 or IN-14 Tubes!

Classic Nixie Tube Clocks

Our next generation of classic Nixie tube clocks perfectly mesh today's technology with the Nixie era technology of the 60's. Of course, features you'd expect with a typical clock are all supported with the Nixie clock... and a whole lot more! The clocks are programmable for 12 or 24 hour mode, various AM/PM indications, programmable leading zero blanking, and include a programmable alarm with snooze as well as date display, 4 or 6 tube, kit or assembled!

We then jumped the technological time line of the 60's Nixie displays by adding the latest multi-colored LEDs to the base of the Nixie tubes to provide hundreds of illumination colors to highlight the glass tubes! The LED lighting can be programmed to any color and brightness combination of the colors red, green, or blue to suit your mood or environment. Then we leaped over the technological time line by integrating an optional GPS time base reference for the ultimate in clock accuracy! The small optional GPS receiver module is factory assembled and tested, and plugs directly into the back of the clock to give your Nixie clock accuracy you could only dream of! The clocks are available in our signature hand rubbed Teak & Maple or clear acrylic bases.

NIXIE **Classic Nixie Tube Clock Kits** **From $229.95**

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 **RF Preamp Kit** **$16.95**

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 **Touch Switch Kit** **$9.95**

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

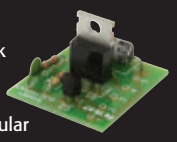
MB1 **Mad Blaster Warble Alarm Kit** **$9.95**

Optically Isolated Module

The hobbyist's headache solver! Converts any AC or DC signal to logic level. The beauty is that the input and output are totally isolated from each other! Output can drive up to 150mA at 40VDC.

OM2 **Optically Isolated Module Kit** **$16.95**

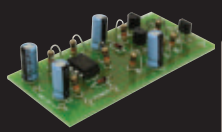
Electronic Siren



What an attention getter! Just hook up a speaker, battery and a switch. Close the switch for an upward wail and release it for the downward return. One of our most popular minikits! Runs on 9V battery.

SM3 **Electronic Siren Kit** **$7.95**

Automatic VOX



This popular VOX switch provides a switched output when it "hears" sound! Use it to key a transmitter, turn on lights, or anything... all controled by your voice!

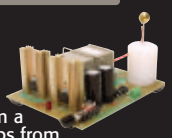
VS1 **Automatic VOX Switch Kit** **$9.95**

Electronic Watch Dog

A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike my Greyhound, eats 2-8VAC or 9-12VDC, not fussy!

K2655 **Electronic Watch Dog Kit** **$39.95**

HV Plasma Generator



Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

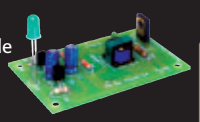
PG13 **HV Plasma Generator Kit** **$64.95**

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 **Ion Generator Kit** **$64.95**

Tickle-Stick Shocker



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 **Tickle Stick Kit** **$9.95**

Speedy Speed Radar Gun

Our famous *Speedy* radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC121 supply.

SG7 **Speed Radar Gun Kit** **$74.95**

Tri-Field Meter Kit

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of

TFM3C **Tri-Field Meter Kit** **$74.95**

Stereo Ear Super Audio Amp

This "Stereo Ear" amp is one of the neatest and handiest high gain amps you will find! Dual high sensitivity electret mics are amplified 50x to provide the ultimate stereo source! Output is 3.5mm jack, runs on 3ea AAA's.

MK136 **Stereo Ear Audio Amp Kit** **$9.95**

Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Asmb.

PR2 **Broadband RF Preamp** **$69.95**

Code Practice Oscillator

A great starter kit for young and old! Learn kit building while building a great little CW practice oscillator to learn the code! Built-in key, built in speaker, and audio tone adjust! Runs on a 9V battery.

CPO3 **Code Practice Oscillator Kit** **$17.95**

Precision PC Plane Antennas

Our LPY series PC antennas continue to be the favorite for virtually all RF and wireless applications. From microwave links, wireless mics, to RFID, we've got you covered. Check our site for details!

LPYSeries **Precision PC Plane Antennas** **from $29.95**

Active Receive Antenna

The EASY antenna, regardless of frequency! This active RX antenna performs like a 60' long wire. Works on all bands, and provides over 15dB of gain. Features auto-bypass when turned off. Runs on 9V battery.

AA7C **Active Receive Antenna Kit** **$59.95**

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